

Teacher's Guide
to the
MODERN
BIOLOGY
Program

by

Otto / Towle / Crider

Here is your examination copy of

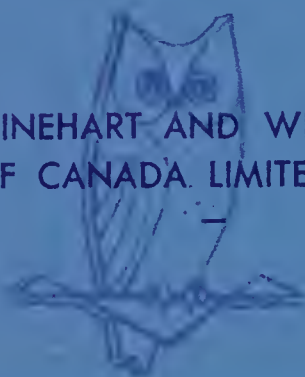
Teacher's Guide to the Modern
Biology Program 4.00

sent for your consideration
with the compliments of

HOLT, RINEHART AND WINSTON
OF CANADA, LIMITED

TORONTO 18

ONT.



PROVINCIAL ARCHIVES
OF ALBERTA

ACC. 73.224

Ex LIBRIS
UNIVERSITATIS
ALBERTAE NSIS

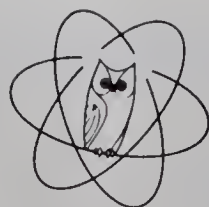


Teacher's Guide
to the
MODERN
BIOLOGY
Program

James H. Otto

Albert Towle

Elizabeth H. Crider



Holt, Rinehart and Winston, Inc., New York

ABOUT THE AUTHORS

JAMES H. OTTO is head of the Science Department at George Washington High School, Indianapolis, Indiana

ALBERT TOWLE is head of the Science Department at James Lick High School, San Jose, California

MRS. ELIZABETH H. CRIDER is a teacher of biology at George Washington High School, Indianapolis, Indiana

COPYRIGHT © 1965 BY HOLT, RINEHART AND WINSTON, INC.

All Rights Reserved

Printed in the United States of America

16706-5725

LIBRARY OF THE UNIVERSITY
OF ALBERTA

CONTENTS

Preface	v
An Overview of the Modern Biology Program	vi
Directory of Supply Houses	viii
Laboratory Apparatus for Use with Biology Investigations	ix

UNIT ONE THE NATURE OF LIFE 1

Chapter 1	The Science of Life	2
Chapter 2	The Living Condition	9
Chapter 3	The Chemical Basis of Life	12
Chapter 4	The Structural Basis of Life	19
Chapter 5	The Cell and Its Environment	24
Chapter 6	Cell Nutrition	33
Chapter 7	Cell Metabolism	40
Chapter 8	Cell Growth and Reproduction	44

UNIT TWO THE CONTINUITY OF LIFE 51

Chapter 9	Principles of Heredity	52
Chapter 10	The Genetic Material	57
Chapter 11	Genes in Human Populations	67
Chapter 12	Applied Genetics	72
Chapter 13	Organic Variation	74
Chapter 14	The Diversity of Life	78

UNIT THREE MICROBIOLOGY 82

Chapter 15	The Viruses	83
Chapter 16	Bacteria and Related Organisms	87
Chapter 17	Infectious Disease	102
Chapter 18	The Protozoans	109
Chapter 19	The Fungi	118
Chapter 20	The Algae	125

UNIT FOUR MULTICELLULAR PLANTS 136

Chapter 21	Mosses and Ferns	137
Chapter 22	The Seed Plants	142

2741912

Chapter 23	Root Structure and Function	145
Chapter 24	Stem Structure and Function	154
Chapter 25	Leaf Structure and Function	161
Chapter 26	Reproduction in Flowering Plants	165
UNIT FIVE BIOLOGY OF THE INVERTEBRATES		174
Chapter 27	Sponges and Coelenterates	175
Chapter 28	The Worms	180
Chapter 29	Mollusks and Echinoderms	188
Chapter 30	The Arthropods	192
Chapter 31	Insects—A Representative Study	197
Chapter 32	Insect Diversity	199
UNIT SIX BIOLOGY OF THE VERTEBRATES		202
Chapter 33	Introduction to the Vertebrates	203
Chapter 34	The Fishes	205
Chapter 35	The Amphibians	212
Chapter 36	The Reptiles	220
Chapter 37	The Birds	223
Chapter 38	The Mammals	225
UNIT SEVEN THE BIOLOGY OF MAN		230
Chapter 39	The History of Man	231
Chapter 40	The Body Framework	234
Chapter 41	Nutrition	239
Chapter 42	Transport and Excretion	244
Chapter 43	Respiration and Energy Exchange	251
Chapter 44	Body Controls	253
Chapter 45	Alcohol, Narcotics, and Tobacco	261
Chapter 46	Body Regulators	263
Chapter 47	Reproduction and Development	265
UNIT EIGHT ECOLOGICAL RELATIONSHIPS		268
Chapter 48	Introduction to Ecology	269
Chapter 49	The Habitat	274
Chapter 50	Periodic Changes in the Environment	279
Chapter 51	Biogeography	281
Chapter 52	Soil and Water Conservation	285
Chapter 53	Forest and Wildlife Conservation	287

PREFACE

This *Teacher's Guide to the Modern Biology Program* is intended to help the teacher make the best possible use of MODERN BIOLOGY. Whether the teacher is just beginning his career or is an experienced master teacher, he is aware of the rapid advances in scientific knowledge, approaches to subject matter, and available equipment for the laboratory. Effective teaching, however, depends, not on subject matter alone, but on the individual teacher and the interest and enthusiasm with which the curriculum is presented.

It is recognized that teachers using identical lesson plans will differ in effectiveness of various topics depending on many factors, such as their backgrounds, the backgrounds of the students, the available equipment, and the locality. Experienced teachers are well aware that their own courses vary from year to year as well as from class to class during any one year. Nevertheless, there is a background of information generally considered basic to the understanding of biology.

Individuality may be achieved by varying the sequence of the information presented to students and by the choosing of related journal articles. Although the units in MODERN BIOLOGY form a logical sequence through the biology course, the book is flexible enough for individual preferences as may be desired.

An Overview of Modern Biology describes the organization of the text. Ideas are offered for the use of the teaching materials at the close of the chapters and units. Suggestions for rearranging the sequence of units and chapters to fit various course outlines, suggested laboratory studies, and reference to the glossary and classification table in MODERN BIOLOGY are also included in this section.

Suggestions for teaching the units and chapters in MODERN BIOLOGY offer a variety of approaches and devices for the teacher. Desired outcomes are listed for each unit. These are followed by teaching devices and points of emphasis for each chapter in the unit. A list of films that are suitable for use are presented in practically every chapter. These film lists include data as to length, whether they are in black and white or in color, and where they may be obtained. The complete addresses of the film producers and distributors are as follows: AIBS McGraw-Hill, McGraw-Hill Book Company, Inc., Text-Film Division, 330 West 42nd Street, New York, N.Y. 10036; Cor, Coronet Films, Sales Department, Coronet Building, Chicago, Ill. 60601; EBF, Encyclopaedia Britannica Films, Inc., Educational Services Department, 1150 Wilmette Avenue, Wilmette, Ill.; Ind, Indiana University, Audio-Visual Center, Bloomington, Ind. 47405. Answers to questions in *Questions for Review* and *Applying Principles and Concepts* are given. Finally, the authors suggest specific exercises in BIOLOGY INVESTIGATIONS that are appropriate to each chapter. Detailed instructions for carrying out each Investigation are provided.

A Directory of Supply Houses with their addresses, from which materials may be obtained, is given on page viii. Lists of laboratory apparatus, materials, and supplies for use with BIOLOGY INVESTIGATIONS appear on pages ix-xv.

The authors are deeply indebted to Mrs. Sheila Feustal and Mrs. Linda H. Doyal for their assistance in preparing parts of the manuscript.

AN OVERVIEW OF THE MODERN BIOLOGY PROGRAM

The eight units in MODERN BIOLOGY form a logical sequence in which each unit grows out of the preceding one.

Unit 1, *The Nature of Life*, deals with the basic principles governing all living things and the methods by which the scientists gain knowledge. The significance of the nucleic acids forms a background for the discussion of cells, the living products of DNA. The cell is treated as the structural and functional basis of organisms. The discussion of cell growth and reproduction presents concepts essential for the understanding of Unit 2, *The Continuity of Life*, in which the principles of heredity are discussed. The role of DNA, gene replication, and determination of genetic characteristics through the coding of DNA molecules are included. Population genetics is discussed in a manner which leads to the understanding of organic variation and the diversity of life on earth today as a result of the evolutionary process.

Unit 3 deals with microbiology, beginning with life at the molecular level—the viruses. The diversity of life in the microbial world is shown by a discussion of the bacteria and related organisms from the standpoint of nutritional requirements and disease production. A treatment of the antibiotics terminates the applied bacteriology section. The protozoans are treated as a group of related protists, followed by discussions of the fungi and algae.

Unit 4 introduces the study of the plant kingdom with the interesting mosses and ferns, graphically showing alternation of generations. This leads logically into a thorough consideration of the most complex forms of plant life, the seed plants.

The invertebrates in Unit 5 continue to point out the diversification of living forms. The variety of habitats from the ocean depths to the mountain peaks provide the requirements for the existence and continuation of various species of these animals. The study of the biologically most successful group of animals, the insects, provides a background essential to an understanding of the vertebrates in Unit 6.

Unit 7 is an expansion of the previous unit and provides a functional treatment of the highest vertebrate, man. The chapter on anthropology treats the history of man in light of accepted theories and Dr. Leakey's recent findings in Africa. The following chapters present the anatomy and physiology of man, and a discussion of the health hazards created by the use of alcohol, tobacco, and addicting drugs. The last two chapters conclude the unit with the importance of ductless glands in the body, and sexual reproduction and development for the continuance of the human species.

Unit 8 reviews many concepts covered in the previous units by discussing the relationships of living organisms to one another and the environment. Many of these ecological concepts will help the student to understand the distribution of life as well as the contribution which each organism makes to its environment. Periodic changes, such as day and night, and the effect of these physical variations on organisms is clearly shown by many familiar examples. The need for everyone to do his part in conserving our natural resources for future generations culminates this last unit.

While the authors recommend the sequence of units in MODERN BIOLOGY, they have planned the book so that certain units may be shifted without losing course continuity. Some schools shift the study of insects to the early part of the fall semester as a personal advantage in securing materials. Others follow Unit 1 with Unit 8 and then proceed to the study of the protists, next the plants and animals, and then to genetics.

Many helpful teaching tools are offered at the end of each chapter and unit in the text. Since terminology is an important tool of biology, *Biologically Speaking* is a good vocabulary summary. Whenever a new word or term first appears in a chapter,

it is defined and pronounced phonetically. The vocabulary list at the end of the chapter serves as a good review, and the student should be certain that he can define the words.

A complete list of biological terms and definitions appears in the *Glossary*. This Glossary should be called to the attention of the student at the beginning of the course. The building of a working vocabulary is essential to success in a biology course. Conversely, a lack of understanding of biological terms is sometimes a common cause of failure in the course.

Questions for Review consists of about fifteen questions based directly on the contents of the chapter. Since these questions follow the sequence of the chapter, a group of questions may be assigned with an appropriate part of the text. These questions are also valuable to the student when used as a self-test in reading comprehension. It is suggested that the student be encouraged to first answer the questions in this manner. Then he can go back to read sections covered by the question, or questions, he did not know. The questions are also suitable for class discussion, and constitute a good basic review for all students.

Applying Principles and Concepts includes more comprehensive questions which are intended to challenge the student. With the accumulation of general information from the chapter, these questions are intended to develop the ability to think clearly and scientifically. Thus the student goes far beyond the simple recall and should be able to make generalizations by applying his knowledge to new situations.

Related Reading is a list of selected books and references from scientific journals which contain information relative to the unit content. A school wishing to expand the science section of its library might consider the purchase of many of these titles.

The *Appendix* contains *A Modern Classification of Organisms*. The authors have included both a traditional and a modern system of listing phyla, subphyla, and lesser classification groups. Reference to these tables may be made throughout the course.

The amount of laboratory and project activity of the biology course will depend on many factors. The time allotted will, necessarily, be a limiting factor. The fullest laboratory and project program possible should accompany the study of biology.

BIOLOGY INVESTIGATIONS, a companion to MODERN BIOLOGY, is written as a laboratory guide. The average student should have no difficulty in completing most of the basic studies. Three types of Investigations are given. Parts marked A contain *basic* or routine studies which are class oriented and require the use of standard materials. Parts marked B contain *experimental* studies which may be class or group oriented, but which require students to interpret their observations. In Parts marked C, a problem is stated for the student to solve. Suggestions for procedure and methods of analysis are given, but these analyses and conclusions reached by the student will be entirely his own, resulting from his understanding of the material. These parts are mainly *research* experiments, ideas, and suggestions probably to be done largely by individual students who are more scientifically inclined and who plan a career in some specialized field of science.

One set of TESTS IN BIOLOGY 1965 and ALTERNATE TESTS IN BIOLOGY 1965 is automatically sent free of charge with each copy of the laboratory manual. The teacher may specify what proportion of TESTS and ALTERNATE TESTS he would like.

The KEY TO TESTS 1965 and ALTERNATE TESTS IN BIOLOGY 1965 is included in this TEACHER'S GUIDE and appears on page 293-326.

DIRECTORY OF SUPPLY HOUSES

BALTIMORE BIOLOGICAL LABORATORY, INC., 1640 Gorsuch Ave., Baltimore 18, Md.

BAUSCH & LOMB, INC., 635 St. Paul St., Rochester 2, N.Y.

CALBIOCHEM, 3625 Medford St., Los Angeles 63, Calif.

CAMBOSCO SCIENTIFIC CO., 37 Antwerp St., Brighton 35, Mass.

CAROLINA BIOLOGICAL SUPPLY CO., Burlington, N.C.

CENTRAL SCIENTIFIC CO., 1700 N. Irving Park Rd., Chicago 13, Ill.

CLAY-ADAMS, INC., 141 E. 25th St., New York 10, N.Y.

CLINTON MISCO CORP., P.O. Box 1005, Ann Arbor, Mich.

DALE SCIENTIFIC CO., Box 1721, Ann Arbor, Mich.

ELGEET OPTICAL CO., INC., 303 Child St., Rochester 11, N.Y.

FAUST SCIENTIFIC SUPPLY LTD., 5407 Schlueter Rd., Madison 4, Wis.

GENERAL BIOLOGICAL SUPPLY HOUSE, INC. (TURTOX), 8200 S. Hoyne Ave., Chicago 20, Ill.

HARVARD APPARATUS CO., INC., Dover, Mass.

MACALASTER SCIENTIFIC CORP., EDUCATIONAL DIVISION, 253 Norfolk St., Cambridge 39, Mass.

NORTHERN BIOLOGICAL SUPPLY, P.O. Box 222, New Richmond, Wis.

SCIENCE EDUCATION PRODUCTS, DIVISION OF B-D LABORATORIES, INC., San Carlos, Calif.

SCIENTIFIC PRODUCTS, DIVISION AMERICAN HOSPITAL SUPPLY, 1210 Leon Place, Evanston, Ill.

SHERWIN SCIENTIFIC CO., N. 1112 Ruby St., Spokane 2, Wash.

THE LEMBERGER CO., P.O. Box 482, Oshkosh, Wis.

TRAVEL-LAB SCIENCE CO., P.O. Drawer M, Manor 1, Tex.

VAN WATERS & ROGERS, INC., P.O. Box 5287, Denver, Colo.

WARD'S NATURAL SCIENCE ESTABLISHMENT, INC., P.O. Box 1712, Rochester 3, N.Y.

WELCH SCIENTIFIC CO., 1515 Sedgwick, Chicago 10, Ill.

LABORATORY APPARATUS, MATERIALS AND SUPPLIES FOR USE WITH BIOLOGY INVESTIGATIONS

The following list includes equipment and apparatus, materials and supplies, glassware and porcelain ware, living specimens, preserved specimens, prepared microscope slides, biological preparations and culture media and chemicals, reagents and stains needed to equip each biology laboratory and student or group of students in a class.

EQUIPMENT AND APPARATUS, PERMANENT

Alcohol lamp, glass or brass (unless laboratory tables are equipped with gas outlets)	1 per 2 stud	secting needles, and probe)	1 per stud
Aquarium, molded glass		Dissecting pan, wax bottom	1 per stud
9 × 5 × 6 in. high, cap. 1 gal		Electrodes, for 1.5-V battery	8
	1 per 2 stud	Fan, electric, small	1
12 × 8 × 8 in. high, cap. 3 gal	6	Flashlight, 6 in.	6
Autoclave (pressure cooker), cap. 25 qts	1	Flashlight, pencil type	6
Balance, analytical, 200 g, sensitivity 0.1 mg	1	Forceps, cover glass, Stewarts, 125 mm	24
Balance, triple beam or trip scale	1	Forceps, slide, Kirbrides, 125 mm	24
Bell jar, high straight form, knob top, 10 × 6 in., or open top to accept No. 4 rubber stopper, 8 × 5 in.	6	Geiger counter	1
Bone shears, 7½ in., with screw lock	1	Hemoglobin scale	6
Burner, Bunsen (if laboratory tables are equipped with gas outlets)	1 per 2 stud	Hotplate, gas or electric	2
Burner, Fisher	2	Hypodermic syringe, cap. 1 ml (tuberculin syringe)	1
Burner wing top, for use with Bunsen burner	1 per 2 stud	Incubator, bacteriological	1
Cage, animal	4	Inoculating needle, 6 in., platinum or nichrome wire, No. 28 B&S gauge	1 per 2 stud
Chair, revolving (desk chair)	1	Kymograph, with accessories, including femur clamp	1
Colony counter, bacterial	2	Lamp, gooseneck	1
Cork board, 12 × 12 in.	6	Lead plate, 4 × 4 in., with 1-cm opening	1
Cork borer set, with handles	1	Light meter, photographic	1
Culture tube basket, round, 6 × 6 in.	6	Magnet, bar or horseshoe	1 per 2 stud
Culture tube rack, to hold 40 tubes	12	Magnifier, folding	1 per stud
Dissecting set (including scalpel or cartilage knife, scissors, forceps, dis-		Magnifier, stand, 3X to 5X	1 per 2 stud
		Magnifier, tripod, 10X	1 per stud
		Microprojector	1
		Microscope, compound, advanced (oil immersion)	2
		Microscope, compound, standard, equipped with l.p. (100X) and h.p. (430 or 440X)	1 per 2 stud

Microscope, widefield, stereoscopic	2	Water bath, shallow form, copper, with removable rings	1 per 2 stud
Microtome, table, with sectioning knife (for free-hand sectioning)	1	MATERIALS AND SUPPLIES, EXPENDABLE	
Osmosis apparatus (double thistle tube with 12 in. graduated stem, 4 × 5 in. battery jar, metal clamp, and membrane)	6	Applicator sticks, box	1
Oven, hot air, electric or gas	1	Battery, dry cell	
Pan, enameled or stainless steel, 2 qt (for preparing media)	2	1.5 V	12
Pan, shallow, enameled or stainless steel, approx. 9 × 16 × 2 in. deep (for dissecting rats in radioactive phosphorous experiment)	1	6 V	1 per stud
Pan, shallow (for drying soil)	6	Bulb, rubber, large size (25 cc), to fit 1 ml transfer pipette	6
Pipette boxes, cylindrical or rectangular, copper or aluminum		Cheese cloth, absorbent, box (70 yards)	1
15 × 2 in. (for 1 ml pipettes)	6	Corks, assorted, sizes 0 to 11, pkg	1
16 × 2½ in. (for 11 ml pipettes)	6	Cotton, absorbent, long fiber, 1 lb. boxes	3
Planchets (for use with Geiger counter)	24	Cover glasses, microscope slide ¾ in. (18 mm) or 7/8 in. (22 mm), ½ oz. boxes	12
Plant press	2	1 in. (25 mm), for hanging drop slides, ½ oz. boxes	4
Prism, 2 × 2 in.	6	Dialysis tubing, 5/8 in. diam, 6 in. length	4 per stud
Projector, motion picture, 16 mm	1	Filter paper, boxes	6
Projector, overhead	1	Flats (for planting seeds)	6
Projector, 2 × 2 in. slide and 35 mm film strip	1	Flower pot, 4 or 5 in.	1 per 2 stud
Pump, hand, air	1	Lancets, blood, disposable	100
Refrigerator	1	Membrane, osmosis, genuine animal	12
Rh typing box	1	Paper, cellophane, rolls, of assorted colors	1 each
Ring support and assorted rings (1 in. to 5 in.) with clamps	1 per 2 stud	Paper, cobalt chloride test papers, 8 × 10 in. sheets	24
Rotator, platform (turntable)	1	Paper, graph, 1 mm divisions, pkg	1 per 2 stud
Screen, projection	1	Paper, kymograph, highly glazed on one side and rough on the other, roll (diam. to fit drum)	1
Spatula, steel		Paper, litmus, vials containing	100
6 in. blade	6	strips	
12 in. blade	6	blue	1
Spectroscope	1	red	1
Stopwatch	1	Paper, Hydrion (pH), range pH 1-11, two 15 ft. rolls in dispenser	3
Terrarium	2	Paper, chromatography, Whatman #1, squares, 8 × 8 in., pkg 100 sheets	1
Thermos bottle, 1 qt	6	Paper, phenylthiocarbamide (PTC) taste test, in vials of 100 strips	2
Timer, interval	1	Paper, radioautograph, glossy, bright	
Tongs, crucible	1 per 2 stud		
Tongs, test tube (holder)	1 per 2 stud		
Tripod (stand), ring size 3 in. i.d.	1 per 2 stud		

contrast, 5 × 7 in., pkg of 100	1
Paraffin, 1 lb pkgs	3
Pencils, colored, assorted 1 each per stud	
Pencils, glass marking, heat resistant, boxes of 12	2
Pinch cock (tubing clamp) 1 per stud	
Razor blade, single edge 1 per stud	
Rubber stoppers, assorted sizes, pkg solid	1
1-hole	2
2-hole	2
Rubber tubing, ¼ in. diam., medium wall thickness	20 ft
Rule, metric and English	
6 in. 1 per stud	
12 in. 1 per stud	
Slide, microscope, plain, 1 × 3 in.	6 per 2 stud
Slide, microscope, single depression (hanging drop)	2 per 2 stud
Thermometer, Centigrade and Fahrenheit (double scale or separate thermometers) -10 to +110°C, +10 to +230°F	1 per 2 stud
Triangle pipe stem, 2 in. sides	1 per 2 stud
Wire, No. 5 gauge, 1 ft. lengths	1 per stud
Wire gauze, asbestos center, 4 × 4 in.	1 per 2 stud

GLASSWARE AND PORCELAIN WARE

Battery jar, cylindrical	6
4 × 5 in., cap. ¼ gal	6
6 × 8 in., cap. 1 gal	1 per 2 stud
Beakers, glass, Griffin low form, Pyrex or Kimax	
50 ml	4 per 2 stud
150 ml	4 per 2 stud
250 ml	4 per 2 stud
600 ml	4 per 2 stud
1000 ml	4
Bottles, aspirator, cap. 1 liter	2
Bottles, dropping, with pipette, 2 oz.	

(60 ml) or 1 oz. (30 ml)	72
Bottles, extra wide-mouth, 8 oz. (or half-pint milk bottles), for culturing <i>Drosophila</i>	24
Bottles, wide-mouth, medium tall, square, screw cap, 2 oz., flint glass	60
Bottles, milk dilution, APHA, 160 ml, graduated at 99 ml, screw cap or Escher stopper (per water or milk sample to be tested)	7
Bottles, narrow-mouth, 8 oz., screw cap, heat resistant glass (for media)	24
Bottles, tincture, mushroom glass stopper, 32 oz.	6
Bottles, wide-mouth, 4 oz. 1 per stud	
Culture dishes, moist chamber, 40 × 140 mm	6
Culture dishes, stacking (finger bowls), 3½ or 4½ in. diam. 1 per stud	
Culture dishes, Petri, Pyrex, or Kimax glass, 15 × 100 mm	250
Culture tubes, 15-16 in. length (for fermentation tubes)	120
Culture tubes, 18 × 150 mm, Pyrex or Kimax glass	250
Cylinders, graduated	
10 ml	1 per 2 stud
50 ml	1 per 2 stud
100 ml	1 per 2 stud
500 ml	6
1000 ml	6
Dishes, evaporating, porcelain, size #0, 3 in. (80 mm)	1 per stud
Droppers, straight tip, 4 in., 2 ml, with bulb (medicine droppers)	6 per 2 stud
Fermentation tubes, plain or glass base (yeast tubes)	36
Flasks, Erlenmeyer, narrow mouth, Pyrex or Kimax	
250 ml	6
500 ml	6
1000 ml	3
Funnels, glass, short stem, 60° angle	
75 mm diam. 1 per 2 stud	
100 mm diam.	12
Funnels, glass, ribbed, heavy molded	6

Glass rod		Escherichia coli, strain B	
3 mm diam.	1 lb	Bacteriophage, T-even, stock culture	
6 mm diam.	1 lb		1 per class
Glass tubing, flint glass		Coleus plants, 6-8 in. high	6
3 mm diam.	1 lb	Crayfish	1 per 2 stud
6 mm diam.	1 lb	Daphnia, culture for 25 students	
Mortar and pestle, porcelain, size #000			1 per class
(65 mm) or size #00 (80 mm)		Drosophila cultures, wild type	
	1 per 2 stud	red-eyed	1 per class
Pipettes, bacteriological transfer, Pyrex		white-eyed	1 per class
or Kimax glass		Earthworms	1 per 2 stud
1 ml graduated at 0.01 ml	6	Elodea, bunches	6
1 ml graduated at 1 ml	7 per 2 stud	Fern fronds, with ripened spores	12
10 ml graduated at 10 ml	6	Fish (goldfish or other living fish), 3-5	
11 ml graduated at 11 ml	6 per 2 stud	in.	1 per 2 stud
Pipettes, fine-tipped, 1 ml, with bulb	6	Fish, 2 sets, one with scales and distinct	
Test tubes, 6 in., Pyrex or Kimax glass	250	body markings and one scaleless and	
		with a more or less solid color pat-	
Thistle tubes, double bulb, 12 in., flint		tern	1 of each per 2 stud
glass	1 per 2 stud	Frogs, grass (leopard), medium or	
U-tubes, glass	6	large	1 per 2 stud
Watch glasses, Syracuse, stacking, 5/8		Geranium plants, 6-8 in. high	6
in. diam.	1 per stud	Hydra, brown or green, culture for 25	

LIVING SPECIMENS

Algae cultures (usually purchased in		Lichens, various types	1 per 2 stud
units sufficient for 25 or 50 students)		Mold cultures	1 per class
or may be collected locally		Aspergillus niger	
Blue-green algae		Neurospora crassa	
Anabaena		Penicillium notatum (for surface	
Gloeocapsa (Anacystis)		growth)	
Nostoc		Rhizopus nigricans	
Oscillatoria		Moss capsules (containing ripened	
Green algae		spores)	1 per stud
Oedogonium		Mushrooms, fresh (Agaricus may be	
Protococcus (Phytoconis) on bark		purchased in grocery stores)	1 per stud
Spirogyra		Planaria, black or brown, culture for	
Ulothrix		25 students	1 per class
Diatoms		Pea pods, fresh, green	100 per class
Axolots, Mexican	12	Protozoan cultures (usually purchased	
Bacteria, stock cultures	1 each per class	in units sufficient for 25 or 50 stu-	
Bacillus subtilis		dents)	
Micrococcus epidermidis		Ameba (proteus or chaos chaos)	
Proteus vulgaris		Euglena	
Sarcina lutea		Paramecium	
Serratia marcescens		Stentor	
		Vorticella	

Rats, white	8
Seeds	
Beans, red	2 lb
Beans, white	2 lb
Corn, field	1 pkg
Corn, genetic, set of viable seeds	1
Peas, smooth	30 per class
Peas, wrinkled	30 per class
Peas, Alderman variety for tall	1 pkg
Peas, Little Marvel or Progress #9	
for dwarf	1 pkg
Radish	1 pkg
Sunflower	1 pkg
Snails, land	1 per 2 stud
Sponge, Microconia	1 per 2 stud
Tadpoles bullfrog or grass (leopard)	
frog, legs undeveloped	4 per 2 stud
Tomato plants, 6-8 in. high	1 per 2 stud
Yeast cultures	
Saccharomyces cerevisiae (brewers and baker's yeast)	1 per class
Saccharomyces ellipsoideus (wine yeast)	1 per class

PRESERVED SPECIMENS

Algae (usually purchased in units sufficient for 25 or 100 students) for use if living materials are not available

Blue-green algae	
Anabaena	
Gloeocapsa (Anacystis)	
Nostoc	
Oscillatoria	
Green algae	
Oedogonium	
Protococcus (Phytoconis)	
Spirogyra, vegetative	
Spirogyra, conjugating	
Ulothrix	
Diatoms	
Brown and red algae	
Fucus	
Chondrus	
Ascaris	1 per 2 stud
Aurelia	1 per 2 stud

Bones, rib	1 per 2 stud
Bones, long	1 per 2 stud
Chiton	12
Clam, fresh-water (mussel)	1 per 2 stud
Corn, genetic, ears showing 1:1 ratio, 3:1 ratio, 9:3:3:1 ratio	12 each
Crayfish	1 per stud
Earthworm	1 per stud
Eye, cow or sheep	1 per 2 stud
Fern frond with sori	1 per 2 stud
Fish, yellow perch (or other species)	1 per 2 stud
Frog, grass (leopard), medium or large	1 per 2 stud
Grantia (Scypha)	1 per stud
Grasshopper, lubber (or other large species)	1 per stud
Heart, beef or hog	6
Lichens, set of various types	1 per 2 stud
Moss, leafy shoot with stalk and capsule	1 per 2 stud
Pig, fetal (embryo), 5-10 in.	1 per 2 stud
Snail, large aquatic or land species	1 per 2 stud
Sponges, various types, set	1 per 2 stud
Sponge spicules, vials for class of 12	2
Squid	1 per 2 stud
Tapeworm, preserved	1 per 2 stud

PREPARED MICROSCOPE SLIDES

Bacteria, three types (coccus, bacillus, spirillum)	1 per 2 stud
Bone, cross section	1 per 2 stud
Earthworm, cross section	1 per 2 stud
Fern prothallus, whole mount	1 per 2 stud
Hookworm, whole mount	1 per 2 stud
Human blood smear	1 per 2 stud
Lilac, cross section of leaf	1 per 2 stud
Mitosis, onion root tip	1 per 2 stud
Mitosis, whitefish blastula	1 per 2 stud
Planaria, longitudinal section	1 per 2 stud
Ranunculus (buttercup), cross section of mature root	1 per 2 stud

Ranunculus (buttercup), cross section of herbaceous dicot stem	1 per 2 stud
Tilia (linden) cross section of woody dicot stem	1 per 2 stud
Trichinella, male and female	1 per 2 stud
Zea mays (corn), longitudinal section of root tip showing root cap and epidermal origin of root hairs	1 per 2 stud
Zea mays (corn) cross section of monocot stem	1 per 2 stud

BIOLOGICAL PREPARATIONS AND CULTURE MEDIA

Antibiotics

Penicillin-G, crystalline	500,000 units
Sensitivity disks with low, medium, and high concentrations of various antibiotics	6 sets

Streptomycin (sulfate)	5 gms
------------------------	-------

Culture media, dehydrated

Agar, Endo	4 oz
Agar, Eosin methylene blue	4 oz
Agar, granulated	1 lb
Agar, Neurospora	4 oz
Agar, Nutrient	1 lb
Agar, Plate count (for milk analysis)	1 lb
Agar, Potato dextrose	4 oz
Agar, Sabouraud dextrose	4 oz
Agar, Tryptone blood	4 oz
Broth, Beef extract	4 oz
Broth, Lactose	1 lb
Broth, Nutrient	1 lb
Egg albumin, powd.	100 gm
Gelatin, granulated	1 lb
Hormone powder, root forming	6 oz
Hormone salve, root forming	6 oz
Lanolin	4 oz
Litmus milk, powd.	1 lb
Milk, powdered	1 lb
Monocalcium phosphate	4 oz
Molasses	1 lb
Olive oil	1 pt
Pancreatin powder	4 oz
Pepsin, powdered	4 oz
Propylthiouracil (uracil)	10 gm

Sera, blood typing, anti-A, anti-B, anti-RhD	1 set
Sodium taurocholate (bile salts)	1 lb
Thyroid tablets, 2 grain	24
Thyroxine crystals	100 mg
Triiodo-L-thyronine, ampule	100 mg
Vitamin B ₁ , tablets	25 gm

CHEMICALS, REAGENTS, AND STAINS

Acetocarmine dye	4 oz
Acetone	1 gal
Acid, acetic, reagent	1 lb
Acid, hydrochloric, reagent	6 lb
Acid, sulphuric, reagent	9 lb
Acid, indol-3-butyric	1 gm
Alcohol, ethyl, denatured 95%	1 gal
Ammonium carbonate	1 lb
Ammonium chloride	1 lb
Ammonium hydroxide	4 lb
Antiseptics, assorted for testing, 2 oz. each	1 set
Barium chloride	1 lb
Benedict's solution, quantitative	32 oz
Brom thymol blue (water soluble)	10 gm
Calcium chloride	4 oz
Calcium nitrate	4 oz
Calcium sulfate	4 oz
Carbon tetrachloride	1 lb
Carmine red	4 oz
Congo red	4 oz
Cupric chloride	1 lb
Dextrose	100 gm
Distilled water, 5 gal bottles	3
Eosin, powd.	25 gm
Ether, ethyl	1 lb
Ether, petroleum	1 lb
Fehling's solution A	32 oz
Fehling's solution B	32 oz
Ferric phosphate	4 oz
Ferric tartrate	4 oz
Ferrous chloride	1 lb
Flour, whole wheat	1 lb
Formaldehyde, USP 40% (Formalin)	3 gal
Gentian (crystal) violet stain, in dropping bottle	1 per 2 stud

Glycerine	4 oz	Sodium hydroxide	1 lb
Gram's differential stains and reagents, set	1 per 2 stud	Sodium hypochlorite	1 lb
Iodine	4 oz	Sodium nitrate	4 oz
Iron filings	1 lb	Sodium oxalate	1 lb
Janus green B	4 oz	Starches	
Lime water	1 gal	Corn	1 lb
Magnesium chloride	1 lb	Potato	1 lb
Manganese sulfate	4 oz	Sudan III soln.	4 oz
Methyl cellulose	4 oz	Sugars	
Methylene blue stain, in dropping bottle	1 per 2 stud	Glucose (dextrose)	1 lb
		Lactose	1 lb
Mercuric chloride	1 lb	Maltose	1 lb
Monocalcium phosphate	4 oz	Sucrose (cane)	1 lb
Peppermint oil	2 oz	Wright's blood stain	16 oz
Petroleum jelly	1 jar		
Phenol (carbolic acid), 5%	4 oz		
Phenolphthalein indicator soln.	16 oz		
P ³² contained in sodium hydrogen phosphate dissolved in physiological saline as a carrier solution	10 microcuries		
Potassium chloride	4 oz		
Potassium dihydrogen phosphate	4 oz		
Potassium iodide	4 oz		
Potassium nitrate	4 oz		
Potassium permanganate, cryst.	4 oz		
Potassium thiocyanate	4 oz		
Quinine sulfate	1 oz		
Sand, fine	1 lb		
Safranin stain, in dropping bottle	1 per 2 stud		
Sea water	1 gal		
Silver chloride	4 oz		
Silver nitrate	4 oz		
Sodium bicarbonate	1 lb		
Sodium carbonate	1 lb		
Sodium chloride	1 lb		

IDENTIFICATION KEYS, CHARTS, AND MODELS	
Algae, fungi, lichens, keys to identification of	6
Clam, snail or squid, charts or models of	1 set
Crayfish, chart or model of	1 set
Ear, model of	1
Eye, model or chart of, showing muscles	1
Fish, yellow perch, chart or model of	1
Ferns, taxonomic keys to	6
Frog, grass (leopard), chart or model of	1
Grasshopper, chart or model of	1
Heart, human, chart or model of	1
Insect charts and identification keys	6
Mitosis, charts or models showing stages	1
Mosses, taxonomic key to	6
Tadpole, chart showing metamorphosis	1
Tapeworm, chart showing life cycle	1
Trees, identification keys to	6

Listed below are stains, solutions, and reagents that may be used in the high school biology course. Formulae and directions for preparation are included. Many of these preparations can be made quite easily in the laboratory. Others, especially the alcoholic solutions of stains, may be obtained from supply houses much more easily.

STAINS

Carmines red, 1% aqueous (for protozoans). Dissolve 1 gram carmine red dry stain in 100 ml distilled water.

Crystal (gentian) violet, aqueous alcoholic (for staining bacteria and other cells).

Add 20 ml saturated alcoholic solution crystal violet (3 grams crystal violet to 20 ml 95% ethyl alcohol) to 80 ml 1% aqueous solution ammonium oxalate (0.8 gram ammonium to 80 ml distilled water).

Gram's iodine (for Gram's stain). Dissolve 2 grams potassium iodide in 300 ml distilled water. Add 1 gram iodine crystals.

Iodine solution (simple stain and starch test). Dissolve 2 grams potassium iodide in 100 ml distilled water. Add 1 gram iodine crystals.

Methylene blue, aqueous alcoholic (for staining bacteria and other cells). Add 30 ml saturated alcoholic solution methylene blue (0.3 gram methylene blue to 30 ml 95% ethyl alcohol) to 100 ml distilled water.

Wright's blood stain (for blood examination). Dissolve 0.5 gram sodium bicarbonate in 95 ml distilled water and add 0.9 gram methylene blue (dye content about 90%). Heat for one hour in flowing steam at 100°C. Cool and filter. Prepare a solution of eosin-Y (water soluble, dye content about 85%) by adding 1.0 gram of eosin to 500 ml distilled water. Add the eosin solution to the filtered methylene blue solution slowly, and with constant stirring, until the blue color is replaced by a purple color with a metallic luster and a black precipitate is formed. Filter, collect the precipitate, and dry it. Dissolve 0.1 gram dry precipitate in 60 ml methanol (reagent quality) and allow to stand for two days. Filter, and bottle for use. (Wright's blood stain may be secured, ready for use, at a biological supply house.)

SOLUTIONS

Ammonium hydroxide solution, dilute. Add 1 part conc. ammonium hydroxide solution to 4 parts water.

Benedict's solution. Add 173 grams sodium citrate and 100 grams anhydrous sodium carbonate to 600 ml distilled water and heat until the chemicals are dissolved. Filter this solution. Add 17.3 grams copper sulfate to 150 ml distilled water. After the copper sulfate has dissolved, slowly add this solution to the sodium citrate and sodium carbonate solution, with constant stirring. Add enough distilled water to bring the whole solution up to 1 liter.

Cobalt paper. Prepare a 5% cobalt chloride solution by adding 5 grams cobalt chloride to 100 ml water. Soak filter paper in solution and dry.

Congo red solution. Add 1 gram of Congo red in 10 ml ethyl alcohol to 90 ml distilled water.

Fehling's solution. *Solution A*. Dissolve 34.66 grams copper sulfate (blue vitriol) in water and dilute with additional water to 500 ml of solution. *Solution B*. Dissolve 173 grams Rochelle salts and 50 grams sodium hydroxide in water. When cold, dilute with additional water to 500 ml of solution. Use in equal parts, but do not mix before use.

Hydrochloric acid, 20%. Add 20 parts conc. hydrochloric acid to 16 parts water. *Do not pour the water into the acid.*

Hydrochloric acid, dilute. Add 1 part conc. hydroxide in 1,000 ml water. Add sufficient excess to produce a saturated solution. Filter to remove excess.

Nitric acid, dilute. Add 1 part conc. nitric acid to 4 parts water.

Nutrient solution (for hydroponics experiment). Dissolve 2.8 grams potassium nitrate, 1.4 grams monocalcium phosphate, 2.2 grams magnesium sulfate, and 0.4 grams ferric sulfate in one-half gallon (approximately 2 liters) distilled water.

Sulfuric acid, dilute. Add 1 part sulfuric acid, conc. to 5 parts water. *Do not pour the water into the acid.*

UNIT ONE

THE NATURE OF LIFE

In introducing this unit and throughout the course it is recommended that the teacher emphasize living things themselves, so that the students will be awakened actually to observe things around them. It is a highly deserved compliment when a student returns to his teacher many years later and comments that his interest in all the wonders about him increases as he continues through life.

Scientists are people trained in the search of knowledge. Although highly motivated and devoted to their work, most scientists have varied and individual interests, including such things as photography, hiking, swimming, boating, skiing, and even surfing. To think of the scientist as an untiring recluse interested only in his one phase of science, rather than as an intelligent but normal being, is not a fair picture nor does it create interest for the purpose of recruiting.

How, then, does one go about being a scientist or learning about life? The student can learn about life by organizing his study in the same manner as a scientist. The methods of science are stressed in Unit One and continued throughout the text as many examples of important findings resulting from organized search are given.

Careful observation often leads to discovery of an important finding for which the scientist was not seeking. The observation of a contaminant mold which killed Dr. Alexander Fleming's bacterial cultures and the thought that the mold might be used to combat disease led to the development of penicillin.

Class discussions on what it means to be alive should eventually lead into the realization that chemical similarities or organisms distinguish them from nonliving things. The organization of various chemicals into the unit of structure of living things—the cell—leads into the key topic for the remainder of Unit One.

OUTCOMES

The study of this unit should result in:

1. Acquaintance with scientific attitudes and methods.
2. Development of technique in planning and performing scientific experiments and in following an outlined procedure.
3. Improvement in ability to make accurate observations and draw valid conclusions.
4. Increase in awareness of the importance of biological knowledge in everyday living.
5. Understanding of problems involved in the survival of living things.
6. Development of a working knowledge of the microscope.
7. Understanding of the nature of protoplasm and its organization in living cells.
8. Understanding of the life functions and the concept that they are universal life activities.
9. Knowledge of the basic structure of matter, elements, compounds, chemical changes, and the relation of living things to their chemical surroundings.
10. Understanding of the chemical activity of the green plant as the link between the inorganic chemical world and the world of organic compounds and biochemical processes.
11. Understanding the role of the DNA molecule as a determiner of heredity.
12. Knowledge of mitosis as a process in which two daughter cells receive identical chromosome and gene content from the mother cell, thus preserving the heredity qualities of an organism and making it alike in all of its cells.
13. Understanding of meiosis in oogenesis and spermatogenesis and the chance distribution of chromosomes and genes during reduction, resulting in variation.

*Chapter 1**The Science of Life*

Since biology is an introduction to laboratory science for the majority of high school students, you will need to emphasize the meaning of science in general and the scientific methods in particular. The technical method will be emphasized in much of the laboratory program. You should definitely stress the importance of following directions, making accurate observations, and recording results. The research method should be used whenever possible, especially in individual, group, and class projects. Be sure that students understand the logical steps in a research method. The microscope is presented in this chapter as a basic tool of the biologist. The student should become familiar with its parts and use, even though he may not use it individually. Students should become aware of the importance of magnification and the contributions made by the use of the electron microscope.

Outside work relating to this chapter might include reports on Anton Van Leeuwenhoek and the perfection of the early microscope, and the contributions made to biology by the use of the electron microscope. A microscopy project might include preparation of slides of such subjects as a mosquito, a fly wing or leg, etc. By comparing observations made with the eye, a tripod magnifier, and a microscope, the value of magnification to the biologist will become more obvious.

Many teachers have been able to stimulate interest and demonstrate the scientific method by using match boxes in which the matches have been replaced with a paper clip, pebble, penny, and a toothpick or other such small objects. The students are cautioned not to open the boxes when they are distributed to groups around the room. The obvious problem to be solved is the identification of the contents of the boxes. The various methods tested, then, become experiments. At the conclusion of the period the teacher can summarize the various procedures used. Groups or individuals have actually used a research method in attacking this problem. None of the groups

will solve the problem completely, but various hypotheses will be made and explored. Some tests will be made as to sound when shaking, weight, size, smell, and number of objects.

P. 2: In discussing the explosion of scientific knowledge in our time, the impetus offered by space research is important. This can serve as an introduction in raising questions about the needs of organisms, the special problems encountered in travel through space such as weightlessness, temperature, oxygen, waste disposal, and food. This topic can also be used for review at the end of the unit when some of these needs will have been discussed in detail.

P. 3, left column: The continuity of scientific knowledge is possible today because of the prevalence of radio, television, and printed matter.

Discuss what basic research is and its importance to applied science. Basic research can be likened to the pieces of a jigsaw puzzle constantly being worked on by many people.

P. 3, right column: Have students bring in superstitions with which they are familiar. Besides the common one of a broken mirror bringing bad luck for seven years, others not so familiar will turn up. These make good oral reading in class.

P. 4, right column: Surgery is dependent on new discoveries and inventions such as anesthesia, a heart machine for open heart surgery, a machine to cleanse the blood of patients with diseased kidneys. Even automation has reached the biological lab with the Autoanalyzer, which accurately performs complex body fluid tests, especially on blood, at the rate of 60 per hour and presents a written record of the test results.

P. 5, right column: Galileo's story shows how scientists were persecuted for a difference of opinion. Nobel is a good subject for a student report—who he was, how the prizes originated, recent winners.

P. 8, left column: The mass use of Sabin vaccine touches on public health. The use of a weakened virus placed on a

sugar cube illustrates how much easier it is to vaccinate people today compared with in Jenner's day.

P. 10, left column: So much scientific literature, good and bad, is published that it is impossible for any one person to read all of it. For this reason abstracts are compiled enabling a person to refer, if interested, to the original article without trying to read all articles presented at symposia or published.

P. 11, right column: Because plants use some light rays more than others, a special bulb called the Gro-lux fluorescent lamp has been developed for use in homes. It is of help to the plant fancier.

P. 13: See the bibliography at end of this unit for a reference that can be used for a report on Van Leeuwenhoek.

Suggested Films

Biology in Today's World (b&w&col, 11 min) Cor

The World of Life (col, 28 min) AIBS McGraw-Hill

MAJOR CONCEPTS

1. Recent accelerated progress in biology has been aided by progress in related fields and by the development of new tools.
2. A scientific method requires logical and orderly steps. The research method is planned by the investigator and its steps may vary widely; the technical method yields reliable data only when the steps in the procedure are followed without variation.
3. If reliable results are desired, investigations must include controls as well as experiments.
4. Pure science is conducted for the sake of knowledge itself; applied science makes use of this knowledge.

ANSWERS TO QUESTIONS FOR REVIEW (Page 17)

1. a. Establishing the science of anatomy by Vesalius, a Belgian; b. theory of circulation by Harvey, an Englishman; c. support of Harvey's theory by Malpighi, an Italian; d. first vaccination by Jenner, an Englishman; e. establishing bacteriology by Pasteur, a Frenchman; f.

method of investigating disease and culturing bacteria by Koch, a German; g. basic principles of heredity by Mendel, an Austrian monk; h. use of arsenic compound in treating syphilis by Ehrlich, a German; i. discovery of penicillin by Fleming, an Englishman.

Many of the recent discoveries are the results of efforts of scientists of the world both past and present. Communication by articles in journals are significant in promoting thought as well as avoiding duplication of effort.

2. a. Chemistry has shown that growth, heredity, response, and everything about life is chemical; b. physics has shown the importance of energy changes; c. oceanography is helping us to understand the distribution of life in the seas; d. earth science has changed our theories on the shape of the earth and helps us to understand its influence on life; e. recent advances in space science may enable man to reach horizons vast distances away.
3. a. Heine, a German physician first recognized polio as a disease involving the nerves; b. Medin, of the University of Stockholm, made extensive studies of polio and published the first report on the early symptoms of the infection; c. Wickman advanced the theory that polio was spread by human carriers; d. Drs. Landsteiner and Popper, of Vienna, conducted studies of polio and succeeded in producing polio infections in monkeys, thus demonstrating that the infection is caused by a virus that attacks the cells of nerves in the spinal cord; e. Salk developed a vaccine which has reduced the incidence of polio by as much as 90 percent; f. Sabin developed an oral virus vaccine composed of live but weakened polio viruses.
4. Injections were given to 53,000 children and the comparison of the incidence of polio among these protected children with children who were not immunized established that gamma globulin was effective. Thus,

the number of samples was significant, and the comparison was made between those injected and those not injected.

5. The Sabin vaccine is composed of live but weakened polio viruses and is taken orally. The Salk vaccine consists of polio viruses that have been made harmless by treatment with formaldehyde and is injected.
6. a. Recognition and definition of a problem; b. collection of related data and information; c. forming a hypothesis; d. experimentation to prove or disprove the hypothesis; e. observation of results; f. organization and recording of data; g. drawing of conclusions; h. accurate reporting of research methods, results, and conclusions.
7. A scientific guess based on known facts.
8. The library puts the knowledge of thousands of people and their techniques in the hands of anyone. This prevents duplication of effort so that experiments of value may continue beyond the life of the original researcher.
9. The control shows the results of an experiment minus the variable. Thus, any observed differences may be attributed to the variable being studied.
10. See question 8 above. Also, if there is any question about the results of the experiment, another scientist can duplicate the results of the experiment if the methods are given. Thus, the method furnishes proof that a reporter is certain of his data.
11. Checking the bacterial content of water, milk, and other foods; identifying various bacteria; checking the strength of antibiotics and other drugs used in medicine; preparing microscope slides; extracting pigments from leaves; following directions in laboratory studies.
12. In pure science, research is conducted for the sake of knowledge itself; applied science makes use of the knowledge gained from pure science.
13. a. Anatomy—the various structures, roots, trunk, leaves, flowers, fruits,

can be studied both macroscopically and microscopically; b. physiology—the various structures studied by the anatomist can be studied from the standpoint of function to determine what each does; c. ecology—the distribution of a species of tree being studied may be observed; also the surroundings and relationships of a single tree or a single grove of similar trees may be made; d. taxonomy—other trees which resemble the one being studied may be observed for similarities and differences; those with the greatest number of similarities may be considered to be related; e. genetics—the reproductive parts of the tree may be observed, collected, and planted. Similarities between offspring may be compared to the parents or parent and data can be tabulated.

14. It consisted of a tube for holding a small fish and a frame in which a magnifying lens was mounted. By holding the lens close to his eye, he could see blood surging through vessels in the tail of the fish.
15. One set is in the eyepiece (ocular) through which the observer views the magnified materials. Other lens systems are contained in objectives. Various combinations of objectives and eyepieces may be made to achieve the desired magnification.
16. Magnification is the enlargement of an image; resolution involves the details that may be seen.
17. Streams of electrons given off by an electrically heated tungsten wire.
18. A phosphorus-coated view plate serves as a screen.

ANSWERS TO APPLYING PRINCIPLES AND CONCEPTS (Page 17)

1. Academic freedom allows a person to explore his own areas of interest, which is the very nature of science.
2. Superstitions are beliefs that are untested and usually unfounded in fact. Scientific beliefs are tested and either proved or disproved.
3. Without the microscope, only the gross structure of living things can be studied. Today, with the electron

- microscope, the subcellular level is revealed.
4. Any scientific concept must be subject to change and revision in the light of new discoveries.
 5. German, Swedish, Austrian, and American scientists were involved in the conquest of polio.
 6. Answers will vary widely. The effect of light on plant growth is described in the text.
 7. The technical method is used for verifying a result and follows an outlined procedure. The research method is used for testing an idea, or hypothesis, and involves experimentation.
 8. Magnifications reach only 1,500 to 2,000 times in the light microscope because there is a limit to which light rays may be dispersed and still produce a visible image. The electron microscope may produce magnifications up to 200,000 times because an electron beam is used instead of light.

Guide to Laboratory Investigations for Chapter 1

INVESTIGATION 1-1

Microscopes—Basic Tools of the Biologist

Scope of the Investigation This Investigation introduces the various types of microscopes used in the laboratory so that the student may become familiar with their parts, differences, and uses. Since the student will use the compound light microscope often during his study of biology, all of the parts studied on pp. 14 and 15 of the text are named, and he is asked to label the parts of the microscope on a drawing that is provided in the manual.

Approximate time required Parts 1, 2, and 3 will require a 50-60 minute period. Students can complete Parts 4 and 5 in a 50-60 minute period.

A Part 1 Simple Microscopes

Suggestions for procedure. Students may use any materials available in the laboratory for study under the simple microscopes. Be sure that each of the students uses the simple microscopes that are in the laboratory. Point out that the simple microscope that can be folded and carried in a pocket is very practical for use in field work. However, when studying materials such as insects and earthworms in the laboratory, it is better to use a stand magnifier and leave the hands free to work with the material being studied.

Student observations—answers to questions.

- (a) Answers will vary—will be 3.5 to 20X.
- (b) Answers will vary.
- (c) Answers will vary—probably 10X.
- (d) Epidermal hairs, if present, veins of the leaf, and portion of blade between the veins.
- (e) So that the light is reflected from the object being studied.
- (f) Answers will vary—probably 2 or 2.5X.
- (g) Answers will vary—probably 125 mm.

A Part 2 The Standard Compound Microscope

Suggestions for procedure. The initial study of the standard compound microscope should be done as a group demonstration. First have the students read the material relating to the parts. Put the instrument in a convenient place where all students can

see it while you are discussing its parts and their functions. Have individual students point to the parts of the microscope as they are discussed. When the students have become familiar with the parts, have them examine the microscope at their station. Each student should be assigned a microscope, if possible, that he will be using for any microscope work he will do during the semester. After the students have examined their own microscope and have become thoroughly familiar with its parts, they are ready to label the drawing provided.

Student observations—answers to questions.

- (a) Usually 7.5X or 10X.
- (b) 75X or 100X.
- (c) 320X to 440X.

A Part 3 The Advanced Compound Microscope

Suggestions for procedure. If you have an advanced compound microscope, have the students examine the triple nosepiece and note the magnification of each objective. Point out that the oil-immersion objective is immersed in a film of oil on the microscope slide. You may use a prepared slide of bacteria to demonstrate the technique of using the oil-immersion lens and its value. Each student should examine the slide and learn to use the condensor on this instrument. If the microscope has a mechanical stage, have the students learn to use it. They will probably experience some difficulty at first with learning to turn the correct screw mechanism for centering material in the field. Point out to the students that this is a valuable attachment for precision work and for measuring materials as they study them under the microscope.

A Part 4 Widefield Stereoscopic Microscope

Suggestions for procedure. The widefield stereoscopic microscope should be set up as a demonstration. A standard compound microscope that you used in Part 2 of this Investigation should be placed on the table with it so that the students can compare the two instruments noting that the widefield stereoscopic microscope has two oculars, paired objectives, low-power magnification, and that the distance between the stage and objectives is much greater than that of the compound microscope. Point out that the wide area between the stage and objectives makes this an ideal instrument for use in the dissecting of small specimens such as insects, earthworms, and flowers.

Have each of the students examine a specimen under the widefield stereoscopic microscope. If the instrument has two oculars, have each student determine the position of the oculars for him to view a clear field. Point out that the material is brought into sharp focus by turning the focusing adjustment, and the specimen should stand out in three dimensions. Have the student move the material in various directions in the field to determine that the specimen appears to move in the same direction that it actually is moved. You can point out that this is not always true of materials moved in a field under other types of microscopes. This will be demonstrated in Investigation 1-2. Point out the advantages of the stereoscopic microscope over the standard instrument. These include more working area for studying materials while viewing them under the microscope, and an erect image that stands out in three dimensions.

Student observations—answers to questions.

- (a) To the right.
- (b) Moved away from the student.
- (c) The stereoscopic microscopic is actually two microscopes in one, one for each eye.
- (d) Both eyes view the same specimen from separate angles resulting in real stereoscopic perception of depth. Materials studied under the microscope are easier to study when they have three dimensions.

- (e) The image is larger than under the previous magnification.
- (f) The size of the field is reduced because less light enters the objectives.

A Part 5 The Electron Microscope

Suggestions for procedure. The biology student will probably never use an electron microscope. However since it is such a valuable instrument for the study of biological subjects and the student will see many electron photomicrographs, we have included it in this Investigation. It is important that he study the principle of the electron microscope. Point out that although the instrument is useful in attaining high magnifications, it also has its limitations because of the low penetration power of the electrons. Since the materials to be studied must be thin and dehydrated, it cannot be used for the study of living things.

The student should follow the directions given in tracing the path of the electrons through the diagram of the optical system of the electron microscope. His reading on pages 15 and 16 of the text and the diagram should enable him to gain an insight into the mechanics of the electron microscope and an understanding of the value and limitations of the instrument.

INVESTIGATION 1-2

Care and Use of the Microscope

Scope of the Investigation This Investigation gives the student specific directions for setting up and using the standard compound microscope that he studied on pp. 13-15 of the text and in Investigation 1-1. As the student uses the microscope in his study of objects, he should become aware of the limitations of the instrument as to magnification and resolution (pp. 14-15 of text).

Approximate time required The student should be able to complete the entire Investigation in two 50-60 minute periods.

A Part 1 Preparing the Microscope for Use

Suggestions for procedure. It is important that the student learn the proper method for caring for his microscope. Caution the student to carry the instrument with his left hand on the arm and his right under the base and in an upright position so that the ocular does not fall out. Emphasize that the lenses should always be cleaned with lens paper. Cheese cloth or other soft material may be used to clean the mirror. If there are particles of dust on the ocular lenses or objective lenses, caution the student to let you remove and clean them. Point out that the diaphragm opening should at first be open to its fullest extent, and then reduced after the student has located his material in a clear field of light. If the mirror has two surfaces, point out that the concave side is used because the light is more intense, since the concave mirror acts like a lens to condense the light from the whole area of the mirror onto that covered by the objective. Emphasize that sunlight should never be allowed to fall on the mirror or into the lenses of their microscope because it is apt to injure the eye and is not good for the instrument. The student should always have a clear field of light before attempting to use the microscope.

A Part 2 Using the Microscope

Suggestions for procedure. Point out to the student that in a wet-mount slide, the cover glass and water as a mounting medium increase the magnification slightly. Plastic cover glasses can be used, but they scratch more easily than glass ones. Alcohol removes oil

8 UNIT 1 THE NATURE OF LIFE

from the slides and cover glasses and is better for cleaning than water. Point out that the materials used for microscopic study must be very thin in order that light can pass through them.

Caution the student to always watch the bottom lens as he lowers the body tube until it reaches the automatic stop. Then he can look into the eyepiece and focus by turning the coarse adjustment toward himself. When the object is in focus, then he can use the fine adjustment for obtaining a clear focus. Caution him that the fine adjustment should never be turned a complete revolution.

Point out that all materials are located under low power and centered in the field before studying them under high power. Demonstrate the technique for turning the revolving nosepiece in changing from one power to another, pointing out that the body tube is not raised before changing from one power to another. The material can be brought into clear focus by turning the fine adjustment slightly toward or away from the viewer. Students should learn to use the microscope with both eyes to avoid fatigue and eye strain.

Student observations—answers to questions.

- (a) It is reversed and upside down.
- (b) Moves to the left.
- (c) Moves toward the viewer—down.
- (d) Less area is included.
- (e) So that the letter will be in the center of the high-power field.

A Part 3 Light Regulation and Resolving Power

Suggestions for procedure. As the student studies the human hair under low power he will be able to see that the hair has depth and that it is thinner in the center than on the edges. It is important for him to watch the specimen carefully as he changes from low to high power. The decrease in the size of the field, the lack of light, and the loss of depth are clearly demonstrated. He should focus on the surface of the hair to see the cracks, oil droplets, and dried skin that are present. Point out that the increase in magnification permits him to see more detail on the surface, but less area of the hair.

Student observations—answers to questions.

- (a) No.
- (b) The center of the hair becomes darker, lines appear in the center, and the color soon becomes uniform.
- (c) Answers will vary according to type of hair used.
- (d) When the center of the hair is in focus, distinct shadows appear on the edges. The hair appears three dimensional. However, when the fine adjustment is turned back and forth, the hair appears flat.
- (e) The hair is not uniform in thickness, being thinner in the middle.
- (f) The high-power field is less bright than the low-power.
- (g) Yes.
- (h) No.
- (i) Decreased.

A Part 4 Measurement of the Microscope Field

Suggestions for procedure. A wide variety of materials such as *Spirogyra*, elodea, paramecia, onion epidermal cells, human cheek cells, and others can be used for this study. The technique for estimating the size of a cell can be used for measuring any microscopic organism or object. Emphasize the fact that the measurement made by the student is an estimate and not an accurate one. Point out that the microscopes used by more advanced students often have a stage and ocular micrometer calibrated for use with the microscope. It will be necessary to explain the relationship between a milli-

meter and a micron. You may wish to introduce the metric system at this time. A millimeter is equal to 1,000 microns.

Student observations—answers to questions.

- | | |
|---------------------|------------------------------------|
| (a) 1.3 to 1.4. | (d) 28 to 31. |
| (b) 1,300 to 1,400. | (e) through (i) Answers will vary. |
| (c) 0.28 to 0.31. | |

Chapter 2

The Living Condition

In contrasting living and nonliving things, this chapter introduces the fundamental characteristics of organisms. The chapter points out a basic concept: life comes only from life and is a condition of protoplasm. Emphasize the critical relationship of plants and animals to their environments, and the survival problems that result. In discussing variations in organisms, the student should understand that certain variations may improve the chances of survival; others may not. He should also understand that no organism voluntarily changes in order to survive; it survives because of the change. Many topics in this chapter lend to class discussions. One of these is the various reasons for man's supremacy among living things.

Interesting projects might include a detailed study of an animal that is nearly extinct. The whooping crane, for example, is almost extinct, not only because it has been shot in its flyways, but because its nesting places are vulnerable to predators. The giant ferns and club mosses that once formed extensive forests in North America are now found in scattered areas where the environmental conditions allow them to grow. The passenger pigeon, dodo bird, mammoth, dinosaur, saber-toothed tiger, woolly rhinoceros, giant sloth, Irish elk, and the mastodon are extinct organisms. The students can form hypotheses regarding form, size, coloration, diet, reproductive habits, or environmental changes that could have brought about their extinction.

A potted plant or an animal that is familiar to the students and native to the area may be demonstrated to the class. Conjectures can be obtained as to how long the organism might live in the classroom.

How long might it live in its natural habitat? An ensuing discussion should bring out many environmental factors and surprise the students with the background of knowledge they already possess. After the discussion and observations of a specific environment have been made, various environments may be compared.

P. 20, Fig. 2-2: A similar superstition was that the Mandrake root had a human form, so that the plant screamed if pulled from the soil. Bestiaries give good examples of fanciful and not so fanciful animals.

P. 21, Fig. 2-3: Use this to review, with open books, the scientific method discussed on pp. 8-12.

P. 22, Fig. 2-4: Students can prepare their own infusions and if microscopes are available, examine the water. Infusions are always a source of wonder to pupils who have not seen living organisms under a microscope before.

P. 27, left column: Discuss here the largest and smallest animals (microscopic animals and the whale) and the same for plants (microscopic and the Giant Sequoia). In between are many variations even among humans who vary from the pygmy to the Watusi of Africa. These are normal variations whereas in humans glandular imbalance may result in the midget of 20 inches or the giant of over 8 feet.

P. 28, left column: Figures for the longevity of wild animals are usually taken from zoos, where living conditions are artificial. Human life spans also differ according to environment. Where conditions are poor, 35 years may be the average length. Geriatrics is the comparatively new branch of biology dealing with older humans and their special problems.

Suggested Films

Characteristics of Plants and Animals
(b&w&col, 10min) Ind

The Unit of Life (col, 28 min) AIBS
McGraw-Hill

MAJOR CONCEPTS

1. The theory of biogenesis states that life comes only from pre-existing life. Thus, origin is significant in separating living from nonliving material.
2. Only living organisms organize protoplasm.
3. Living things have a constant energy requirement.
4. Cells are the basic units of structure and function of living organisms.
5. Living organisms have a definite life span which includes: beginning, or origin; growth; maturity; decline; and death.
6. Living organisms have a critical relationship with the environment and are capable of responding to its changes.

ANSWERS TO QUESTIONS FOR REVIEW (Page 32)

1. An organism is a complete and entire plant or animal.
2. Life arises from pre-existing life.
3. Insects arising from mud; decaying meat changing into maggots; mice being produced from grain and sweat; frogs and fish being produced from clouds in a thunderstorm; geese forming from barnacles.
4. Redi placed some pieces of snake, some fish, some "eels of Arno," and a slice of milk-fed veal in each of four clean jars. He then prepared a duplicate set of four jars. One set of jars was left open. The other, which we would designate as a control, was covered and securely sealed with wax. Flies were attracted to the open jars and laid eggs which developed into maggots. The sealed jars contained no maggots.
5. Needham said that after boiling the broth and closing the containers with stoppers, organisms developed and grew in the broth. Thus, he thought that they developed by spontaneous generation.

6. Spallanzani made an infusion by boiling seeds in water. He showed that when it was left open to the air, microorganisms developed. Then he loosely stoppered some in which microorganisms still developed. Then, using stoppered flasks, he boiled them for varying lengths of time and showed that the number of organisms developing decreased inversely with the length of boiling time. When he boiled the infusion in a sealed flask for 30 minutes, no microorganisms developed as long as the flask was sealed. However, when he opened it to the air, microorganisms soon developed.
7. The flasks had long, S-shaped necks. The dirt and dust which contained microorganisms were trapped in the S-shaped curve of the flasks. Therefore, they did not reach the sterile broth and growth did not occur in the flask.
8. Protoplasm is a combination of certain proteins, carbohydrates, fats, and other substances organized into a system by a living organism. It is a state of chemical activity which may be called the living condition.
9. Assimilation is the reorganization of substances to form protoplasm characteristic of the organism in which it is formed. Nonliving substances, such as crystals, grow by a deposition of a solid on the surface of the mass.
10. In assimilation, large complex molecules are formed as a result of biochemical activities of the existing protoplasm.
11. Beginning, or origin; growth; maturity; decline; death.
12. Cells enter into the make-up of every organism.
13. Irritability is the ability to respond to a stimulus.
14. Light, moisture, oxygen supply, temperature, air currents, soil conditions, variations in the earth's surface.
15. It must migrate, adapt, or perish.
16. Conditions in an environment may change rapidly or over a period of time. The variations of a species

that are of survival value in allowing it to adapt to these changes will be the ones that will be perpetuated through heredity. This method of the development of characteristics that suit a species to the environment is called adaptation.

ANSWERS TO APPLYING PRINCIPLES AND CONCEPTS (Page 32)

1. The fact and the importance of the control group which Redi used should be discussed. These are still important factors today.
2. Boiling had not destroyed the property of the liquid in the flask to support microorganisms, nor had the experiment excluded the "active principle" of the air thought to be necessary for spontaneous generation. Both the liquid and the air in the flask were suitable for the growth of bacteria, molds, and other organisms if they were introduced from an outside source. When the

3. Waste products are toxic to cells and must be removed. As tissue increases in mass, it becomes more difficult for the internal cells to receive nourishment and eliminate wastes. Organisms have definite life spans, even though their substances have the capacity for indefinite life.
4. Responses vary from the simple tropisms of plants to complex instinctive behavior such as migration.
5. All organisms must satisfy the organic needs (food, water, and oxygen concentration), but the more closely related organisms find the competition more severe; as they require these needs in the same form. Many examples can be drawn from the class in a discussion.

Guide to Laboratory Investigations for Chapter 2

INVESTIGATION 2-1

Growth Characteristics of Living Organisms

Scope of the Investigation In this Investigation the student will repeat the classic experiments conducted by Spallanzani, Pasteur, and van Helmont. In performing the experiments of Spallanzani and Pasteur that they studied on pp. 23-25 of the text, he should make some observations that will help him to refute some of the theories relating to the origin of microorganisms (pp. 22-23 of the text). He should also gain a better understanding of biogenesis (p. 25 of text).

Students who do the C-level Part will repeat the plant growth experiment conducted by van Helmont in which he concluded that the living matter in his willow tree came entirely from water. However, the students should be able to conclude that some of the substance must have come from other sources, perhaps from the air and soil.

Approximate time required Preparation and sterilization of the materials for Part 1 will require one 50-60 minute period. The experiment will run for 72 hours, but other laboratory activity can be carried on during this interval. Collection and recording of data will require one 50-60 minute period.

Part 2 will require from three to four weeks. The soil can be dried in an oven before class time. The initial work of planting the sunflower will require 30 minutes. The observations made at the end of the experiment will also require 30 minutes. This experiment can be continued while other laboratory work is being done.

Suggestions for procedure. You should demonstrate the technique for inserting glass tubing in the stoppers. Caution the students to insert the tubing by turning instead of

pushing it into the stopper. The nutrient broth should be completely dissolved before it is put in the flasks. It is necessary to use a heat-resistant glass-marking pencil because the flasks are heated to a temperature of 250°F during sterilization. Follow the directions for preparing the flasks and check carefully to see that the students put them in the proper place following sterilization. The flasks are covered with a aluminum foil rather than putting the stoppers into them during sterilization because as they cool, the rubber stoppers are often drawn into the neck of the flask, and cannot be removed.

The dropping pipettes have to be clean but not sterilized. Bacteria are so small that darkening the field helps in studying them. Have the students study each of the flasks carefully and record their findings on the table provided. This is their evidence for interpreting their data.

Interpretation. There is no proof that living organisms were present in the broth before incubation. Flasks C, D, E, and F provide evidence that there were not. There is no proof of spontaneous generation. Flasks C and E, both of which were sterilized and then exposed to the air, demonstrated that heat did not destroy an "active principle" in the broth. These same flasks provided proof that bacteria were introduced with air. The final disproof of spontaneous generation was provided by flask F, the Pasteur flask, in which all conditions for growth were present but in which the air was freed of bacteria in the swan-necked tube.

C Part 2 Plant Growth and Soil Substances

Suggestions for procedure. The student should select a healthy three-inch sunflower seedling for his study of plant growth and soil substances. All of the moisture must be removed from the soil particles before weighing. Caution the student to use care in removing soil and washing the roots at the beginning and end of the experiment. Rough handling can injure the delicate roots and destroy the root hairs. The plant should be checked daily to determine whether it needs water.

Analysis and conclusions. The gain in weight is obvious from the calculations made on the soil and sunflower at the end of the experiment. There should be little difference in the weight of the soil at the beginning and end of the experiment. Thus, the student should conclude that the substances in the plant that were responsible for its increase in weight must have come from other sources than the water. He can draw two conclusions that it came from the air or that it came from the soil. Point out to the student that his conclusions are merely theories, since he has no data to support them.

Chapter 3

The Chemical Basis of Life

Throughout the study of biology, reference will be made to chemical substances and chemical changes as they relate to food synthesis, oxidation, and other biochemical processes. This chapter presents an excellent opportunity to stress the interrelationship of the various branches of science. There is a discussion of the elements most essential to living things, and the student should understand that organisms are not composed of elements in their pure form, but rather of compounds containing them.

The significance of the relationship of proteins to living things should be emphasized. In addition, enzymes (which are proteins) play an important role in the life of an organism. Point out to the students that enzymes have two roles and that one is constructive, the second one destructive. The build-up of the organic world from common inorganic compounds should be stressed. The study of energy and energy-yielding processes of a cell provides a background for understanding of cycles in

nature as well as energy changes during photosynthesis, cell oxidation, and other chemical processes performed in living things.

Students with special interest in physics can plan several demonstrations to show energy changes. These might include a transfer from chemical energy stored in a battery to electrical energy, then to light and heat energy in a light bulb, or to mechanical energy in a bell. Some students may wish to make a model or a large diagram of a DNA molecule.

P. 35: A well-organized lesson on elements, compounds, and mixtures will serve to introduce biochemistry. In your presentation take into consideration the intelligence and background of the students. Have in your mind facts about the substances you use. For example, talc is the rock you wear; sulphur is mined with hot water.

Students could determine the characteristics of the substance shown to them: weight, color, hardness, surface texture. How many substances appear to be here? What is an element? Check with the definition on p. 760. Sulfur is a good substance to use here. Discuss a compound (copper sulfate) in the same way. Check with the definition on p. 758. Discuss a mixture the same way. Copper sulfate in water is readily visible to the class. The mixture definition is on p. 765. List several objects and have students tell whether they are elements, compounds, mixtures (desks, paper, cake, table salt, water, and window panes). List some common elements and their symbols: C,H,O,Na,Fe,Ag,Cl. Use pp. 84 and 86 and explain equations.

P. 37, Fig. 3-4: Radioactive iodine is also used with the scanner to determine whether metastases have developed from the thyroid in other parts of the body.

P. 44, left column: Radioactive carbon (C^{14}) is important. See p. 543.

P. 47, left column: Refer to the cholesterol controversy and ads as well as labels on cans of fats and oils. Cholesterol is normally formed by the liver.

P. 48, left column: Vegetarians need a variety of amino acids. Enzymes are important in industry, even being used in the processing of textiles. Bring in samples of

chocolate-covered cherries with the liquid centers. Ask how the syrup gets into the chocolates and you will get a variety of answers. The cherries are first coated with solid sugar containing an enzyme and then coated with chocolate. On standing, the sugar is converted by chemical action to a liquid.

Suggested Films

Building Blocks of Life (b&w, 30 min) Ind
Carbon and Its Compounds (b&w&col, 11 min) Cor

Chemical Bond and Atomic Structure (b&w&col, 16 min) Cor

Chemical Organization of the Cell (col, 28 min) AIBS McGraw-Hill

From Atoms to Organisms (col, 28 min) AIBS McGraw-Hill

What Makes Atoms Stick Together? (b&w, 30 min) Ind

MAJOR CONCEPTS

1. Matter is anything that occupies space and has weight, while energy is the capacity to do work.
2. Elements are made up of atoms, which in turn are made up of subatomic particles in definite configurations.
3. Atoms may combine to form compounds by sharing electrons or by transferring electrons. Such combination involves the transfer of energy and is a chemical change.
4. The physical combination of elements does not involve energy transfer and results in mixtures rather than chemical compounds.
5. Protoplasm contains about 18 elements suspended as ions and molecules in a colloidal system.
6. Protoplasm has the unique ability to build organic compounds from inorganic compounds. These organic compounds include carbohydrates, fats and related substances, proteins, and nucleic acids.
7. Biosynthesis is controlled by DNA, the master molecule, which by the arrangement of its organic bases, determines enzyme synthesis and thus all chemical activity.

ANSWERS TO QUESTIONS FOR REVIEW (Page 53)

1. A physical change is illustrated in the condensing of water vapor to drops of water and the freezing of water to form ice; also, the crumbling of rock to form sand, gravel, or clay. The burning of wood to form gases, vapors, and ash, and the combination of iron and sulfur to form iron sulfide are examples of chemical changes.
2. Potential energy is energy of position, such as that possessed by a boulder at the top of a hill. Kinetic energy is energy of motion, which the boulder will have as it rolls down the hill.
3. Protons have a positive charge and occupy the center of the atomic nucleus; electrons have a negative charge and revolve around the nucleus; and neutrons have no charge and are found in the nucleus of most atoms.
4. The atomic number of an atom refers to the number of protons in the nucleus of that atom. The atomic weight of an element is the sum of the protons and neutrons in the atom. It is also termed the atomic mass.
5. Isotopes are different forms of an element in which the number of neutrons vary.
6. The particles in the nucleus determine the mass of an atom. The number and arrangement of electrons determine its chemical activity.
7. A covalent bond is a force that holds two or more atoms together as a result of the sharing of pairs of electrons. An ionic bond is the force that holds two atoms together by the transfer of electrons from one atom to another.
8. A molecule of most gaseous elements (oxygen, nitrogen, chlorine, and hydrogen) consists of two atoms. The molecule of most elements consists of a single atom. In these examples, the molecule is not a compound. Many compounds are molecular. Some molecular compounds are carbon dioxide, carbon monoxide, and water.
9. a. The elements forming a compound are joined by chemical bonds, either covalent or ionic; the substances forming a mixture are associated physically or mechanically, rather than chemically; b. a chemical change is necessary to separate the elements combined in a compound; the substances in a mixture can be separated by physical means; c. the elements forming a compound combine in definite proportions; the proportions of substances in a mixture are variable rather than definite; d. a compound has its own physical and chemical properties which are different from those of its constituents; a mixture has the properties of the various substances forming it; e. the formation and decomposition of a compound involve energy changes; energy changes are not involved in a chemical action in forming a mixture.
10. The dissolving medium of a solution is the solvent; the dissolved substance is a solute.
11. In molecular solutions, solute molecules are evenly dispersed through solvent molecules. Molecular solutions may involve liquids and gases, two liquids, or a liquid and a solid, such as sugar and water. In ionic solutions there is a separation of particles into charged particles which will conduct electricity. NaCl in water will conduct electricity; therefore the solution is an ionic one.
12. The size of the particles.
13. The change from a gel to a sol or from a sol to a gel is called phase reversal. Gelatin is a good example of a reversible colloid. Temperature may cause phase reversal.
14. Temperature may change a gelatin gel to a sol or the reverse. Egg albumin is changed from a sol to a gel as the temperature is increased, but it cannot be reversed.
15. Water, carbon dioxide, and mineral compounds. The green plants, however, provide an essential link in the utilization of these essential inorganic compounds by animals.
16. Biosynthesis is the organization of

organic molecules by living organisms.

17. Monosaccharides are six-carbon, or simple, sugars with a formula of $C_6H_{12}O_6$. Disaccharides are double sugars with a formula of $C_{12}H_{22}O_{11}$. They are formed by the combining of two six-carbon sugar molecules and the removal of one molecule of water. Polysaccharides are complex carbohydrates composed of glucose units in chains, in which each unit consists of six-carbon sugar molecules from which a molecule of water has been split off. The formula for a polysaccharide is $(C_6H_{10}O_5)_n$. Examples of each kind of sugar are fructose, lactose, and glycogen.
18. Glycerin and fatty acids.
19. Protein molecules consist of complex groups of smaller units known as amino acids.
20. An enzyme is an organic catalyst. All enzymes are protein molecules.
21. The DNA molecule is pictured as a twisted or spiral ladder; the strands forming the side pieces are composed of alternating units of deoxyribose sugar, a five-carbon sugar, and phosphates. The links between these strands, or steps of the ladder, are composed of pairs of nitrogen-containing bases. These bases consist of four kinds of organic molecules, belonging to two classes of compounds: purines, adenine and guanine; and pyrimidines, including thymine and cytosine.
22. The nucleotide, consisting of a series of units of a sugar, an attached purine or pyrimidine, and a phosphate group, is constant. A and T are always joined, as are G and C, though their positions (right and left) may vary. There is also variation in the linear sequence of the base pairs.

ANSWERS TO APPLYING PRINCIPLES AND CONCEPTS (Page 54)

1. Hydrogen, having one proton and one electron, is the simplest element. Uranium, the most complex natural element, has 92 protons and 92 electrons.
2. Carbon tends to share the four electrons in its outer shell with those of other atoms, making possible a variety of configurations.
3. Enzymes act as catalysts in the processes essential to maintaining life. These include the building up, or synthesis, of substances, as well as the breakdown of matter. Enzymes are also indispensable in the energy-yielding processes of the cell. There is an enzyme for every chemical activity of an organism.
4. Answers will vary. Many will probably say DNA because it controls the synthesis of every other substance and is unique to life.
5. Reproduction is a characteristic of life itself; therefore, it would be essential that a key molecule such as DNA be able to be duplicated in some way. Thus it is now attributed to be the genetic code of heredity.
6. DNA, in the arrangement of its base pairs, bears the genetic code that determines exactly what an organism will become. DNA, together with its product RNA, controls the organization of enzymes. These in turn determine all of the chemical activity of the cell. When we say that living things have a unique chemical organization, we are really saying that DNA molecules regulate all phases of cell biochemistry.

At times DNA molecules make chemical mistakes during replication. A different DNA molecule appears and transmits its new structure to other molecules as it replicates. A genetic variation in an organism results.

Guide to Laboratory Investigations for Chapter 3

INVESTIGATION 3-1

Solutions, Colloids, and Suspensions

Scope of the Investigation This investigation presents an opportunity for the student to investigate the solid-liquid systems that he studied on pp. 41 and 42 of the text. As he compares each of the systems with respect to settling effect, appearance in a beam of light, filtration effect, passage through a membrane, and the ability to form a gel, he should develop a better understanding of the concept of solutions, colloids, and suspensions. His observation of a phase reversal in the agar and the inability of the egg albumen to return to a liquid state should aid in his understanding of phase reversal (p. 42 of text).

Approximate time required Parts 1 and 2 will require one 50-60 minute period. Time may be saved by soaking the dialysis tubing before the class convenes. Then, Section 5 of Part 1 can be started and left for study while the other Sections are in progress. Section 4 may also be set up and left to filter while other parts are being done.

Part 3 can be completed in 30 minutes.

A Part 1 Properties of Solutions, Colloids, and Suspensions

Suggestion for procedure. All the test liquids should be prepared according to directions in the student manual. Since tap water often contains some dispersed particles that might interfere with the results, distilled water is recommended for use in preparing the test liquids. Glucose (sugar) may be substituted for salt in the preparation of the solution. However, if glucose is used, Benedict's solution should be used for the test for passage through a membrane. Use clean sand for the suspension. The sand particles should be of uniform size, if possible.

In testing for the appearance of test materials in a beam of light, make sure that the students use a clean stirring rod for stirring the test liquids in each beaker. The use of a rod that had been used in another beaker could result in incorrect data.

Demonstrate the method for folding filter paper and have the student moisten the paper before placing it in the funnel. Extreme care should be used with the nitric acid. If it is added too quickly to the test liquid, it may boil out onto the student's skin. The yellow color indicating a positive protein test will be very evident if the gelatin passed through the filter. The ability of the gelatin to pass through will be dependent on the type of filter paper used. Students may obtain a negative result, although it should be positive.

You may have the student substitute a thistle tube with a membrane stretched over the mouth for the test for penetration through a membrane in Section 5. However, the dialysis cellulose tubing method suggested in the Investigation is easier to use. The cellulose dialysis tubing in assorted sizes and lengths can be purchased from a biological supply house. The 6-inch length of tubing suggested can be cut from a larger piece and should be soaked in distilled water for one-half hour to soften it. If it is not prepared ahead of time, it can soak while the test liquids are being prepared. Be sure one end is tied securely before the test liquids are poured into the soaked tubing. If they are tied loosely, the entire tube and contents may fall into the beaker of distilled water. The portion of the tubing containing the test liquid, often called the "belly," should be submerged in a beaker of distilled water.

Student observations—answers to questions.

- (a) Three.
- (b) The size of the particles.

- (c) No, sand and clay are not filterable.
- (d) Table salt and gelatin.

B Part 2 Determining the Properties of a Clay Suspension

Suggestions for procedure. The use of various kinds of clay will show that clay and water may show properties of either colloids or suspensions, depending on the size of the clay particles present.

Interpretation. If the clay particles are large, like the sand, they will settle out. If they are smaller than the sand, they will form a colloid similar to the gelatin and water. A beam of light will pass through the clay and water if it is a suspension like the sand, but will be diffused if it is a colloid. Clay does not pass through a filter; nor does it form a gel in water. In this respect, the mixture resembles the sand.

B Part 3 Study of Reversible and Irreversible Colloids

Suggestions for procedure. The agar should be poured into a culture tube and allowed to gel before the students come to class. The egg albumen can also be ready in advance. The liquefying of the agar when heated and solidifying when cooled is an excellent demonstration of a phase reversal. The solidification of the egg albumen by heating and its failure to return to a liquid state should give the student a better understanding of the meaning of an irreversible colloid.

Student observations—answers to questions.

- (a) 99°C.
- (b) 38°C.
- (c) Because it changes from a gel to a liquid state, then to a gel.
- (d) Gelatin and protoplasm.
- (e) Answers will vary.
- (f) No.
- (g) Doesn't.
- (h) Irreversible.

Interpretation. Water freezes at 0°C (32°F) and boils at 100°C (212°F). Gasoline, milk, alcohol, and soft drinks also undergo changes with temperature variations.

INVESTIGATION 3-2

Study of Organic Compounds Synthesized by Organisms

Scope of the Investigation The burning of the sugar cubes in Part I and the formation of a carbon residue bears out the discussion of carbon as the key to organic compounds on p. 43 of the text. This Part also demonstrates the principle of a chemical change studied in Investigation 3-1. As the student performs the various tests on foods, he is demonstrating the presence of compounds synthesized by organisms that he studied on pp. 44-48 of the text. His study of the behavior of organic nutrients in water should increase his understanding of solutions, colloids, and suspensions that he studied in Investigation 3-2.

Approximate time required Part 1 will require about 10 minutes. Students should complete Part 2 in 30 minutes. If all of the tests are performed in Part 3, it will require at least two 50-60 minute periods. Part 4 can be completed in 20 minutes.

A Part 1 Test for the Presence of Carbon in a Carbohydrate

Suggestions for procedure. As the student observes the dissolving of the sugar and the production of heat and water, he should recall his study of a chemical change in Investigation 3-1. The black residue in the crucible is visible evidence of carbon in the sugar. Other materials such as potatoes, beans, and egg can be used for the study.

Student observations—answers to questions.

- (a) They dissolve.
- (b) Water particles have formed on the walls of the tube.
- (c) Heat.
- (d) Carbon.
- (e) They combined to form the water.
- (f) Chemical.
- (g) New substances were formed during the burning of the sugar.
- (h) Yes.
- (i) Chemical energy in the sugar was changed to heat energy.

A Part 2 Test for Presence of Organic Nutrients

Suggestions for procedure. Point out that certain chemicals will react with each of the four classes of foods and by a color change indicate that a particular food is present. For example, iodine turns a blue-black or purple when put on a substance containing starch. Fehling's solution turns from blue to brown or orange when heated with certain sugars. Nitric acid turns any material containing protein yellow. Sudan III, a dye, dissolves fat and colors it a reddish orange. This Part introduces the student to basic chemical tests he will use in Part 3 and in other Investigations.

Student observations—answers to questions.

- (a) Deep blue.
- (b) Yellow, green, or red.
- (c) Brick red.
- (d) Positive.
- (e) Little or no change.
- (f) Negative, if sugar is pure.
- (g) Blue-black.
- (h) Positive.
- (i) Yes.
- (j) Oil droplets are formed; these become pink.
- (k) Positive.
- (l) Yellow.
- (m) Orange.
- (n) Positive.

B Part 3 Identification of Unknown Organic Nutrients

Suggestions for procedure. Students will use the chemical tests they used in Part 2. As they perform the various tests, they will find that organic nutrients synthesized by organisms are often present in the cells of foods, but are not easily recognized. Their study of these foods should provide a better understanding of biosynthesis.

Interpretation. Foods required by the plant are carbohydrates (starches and sugars), protein, and fat. During photosynthesis the plant cells produce these foods and store them in various parts of the plant. In some plants, they may all be stored in one area; in others the foods may be distributed in the plant tissues. Not all plants synthesize all the food materials for storage.

Chapter 4

The Structural Basis of Life

Point out to the students that a real knowledge of cellular biology is essential in any area of biological study. In teaching protoplasm, emphasize that it is a unique substance with a particular combination of properties which gives it the potential of life. Point out that protoplasm is not a static material, and that it undergoes many chemical and physical reactions every second. Emphasize that the large quantity of water in protoplasm enables the molecules to undergo many chemical reactions with one another. The specialization of protoplasm in forming the various living structures of a cell is one of the most basic studies in the entire biology course. The study of specialization of cells continues in the study of tissues, organs, and systems, which allow division of labor and interdependence in higher forms of life.

P. 56, left column: Here is a good time to review the electron microscope (see p. 15). Some students might like to report on the tools and techniques used to investigate cell structure. Others might like to grind material in a food blender and then centrifuge it to determine the relative density of its parts. Some students might prefer to make a bulletin board of a large generalized cell or a three-dimensional model, labeling the parts and stating the functions of each part.

P. 59, Fig. 4-3: Use this to point out the similarities and differences between plant and animal cells.

P. 61, right column: Colorful leaf changes are seen in a few localities in the world. Trees differ in their seasonal colors. In discussing these changes, introduce the material on p. 345, which will then seem familiar to students when you reach that section of the text.

P. 62, right column: Since the hydrangea can be colored from white to pink or blue by regulating the acidity of the soil, have a student investigate how this is done. Florists sometimes carry specimens of both pink and blue.

P. 64, right column: Radioautography and radioactive isotopes are important tools

in medicine to use in finding metastatic cancer lesions. Another important recently developed tool in the fight against this disease is the use of Tetracycline. The drug concentrates more and stays in longer in cancer cells than normal cells. When fluid is drained from the body area involved, is centrifuged, spread on filter paper, dried, and examined under ultraviolet light, a positive result is indicated by a bright yellow fluorescence.

Suggested Films

Cell Biology: Life Functions (b&w&col, 19 min) Cor

Cell Biology: Structure and Composition (b&w&col, 13½ min) Cor

What Is a Cell? (col, 28 min) AIBS McGraw-Hill

MAJOR CONCEPTS

1. The cell theory states that cells are the units of structure and function of all living things; and that cells originate from pre-existing cells by reproduction.
2. All the processes of a living cell involve energy transformations provided by chemical activity within the cell. The cell processes are nutrition, digestion, absorption, synthesis, respiration, excretion, secretion, movement, response, and reproduction.
3. The nucleus is the control center of all cell activity. The DNA-rich nucleoproteins direct the cellular processes and transmit the hereditary characteristics of the cell.
4. Cytoplasm contains various organized bodies called organelles, each associated with a specific activity of the cell.
5. The chlorophyll-containing chloroplasts of a green plant cell allow the cell to make food from inorganic substances. This places the green plant in a key biological position, as most living organisms depend on their food-making activities.
6. Plant cells are enclosed in a rigid cellulose cell wall which is not present in animal cells.

7. The organization of organisms is considered to be on various levels: cellular; colonial; multicellular. Cell specialization provides diverse tissues which comprise multicellular organisms.

ANSWERS TO QUESTIONS FOR REVIEW (Page 69)

- ① 1. Robert Hooke observed the cell walls inside of which once were living cells.
2. a. In 1835, Dujardin described the contents of the cell and named the material *sarcode*, a term later to be changed to protoplasm; b. in 1838, Schleiden proposed that all plants are composed of cells; c. in 1839, Schwann made a similar statement regarding animal structure; d. the work of these men established the cell theory.
- ② 3. a. The cell is the unit of structure and function of all living things; b. cells come from pre-existing cells, by cell reproduction.
- ③ 4. The processes of a cell are: nutrition, digestion, absorption, synthesis (assimilation), respiration, excretion, secretion, movement, response, and reproduction. All the cell processes except response and reproduction are included in metabolism.
- ④ 5. The light microscope shows the nuclear membrane as a barrier, but it appears as a porous structure under the electron microscope. Nuclear substances pass freely into the surrounding cell substance. RNA molecules pass into the cytoplasm and control the organization of enzymes. These enzymes in turn control the synthesis of proteins and all other chemical activities of the cell.
- ⑤ 6. The plasma membrane is a gel composed of protein and fatty materials. The bulk of the cytoplasm is a semi-fluid material which may change from a sol to a gel state or the reverse process.
7. The endoplasmic reticulum is a complex system of membranes which tend to lie parallel to one another and fasten to the plasma membrane and nuclear membrane.

8. The ribosomes are tiny dense granules attached to the endoplasmic reticulum and lying between its folds. They contain large amounts of RNA and some contain protein-synthesizing enzymes. They are the protein factories of the cell.
- ⑦ 9. The mitochondria are rod-shaped bodies in the cytoplasm. They are centers of cellular respiration, during which energy is released to support cell activities.
10. These small groups of parallel membranes in the cytoplasm near the nucleus are most numerous in cells composing glands.
- ⑩ 11. Because they contain the chlorophyll involved in the organization of carbohydrates from carbon dioxide and water.
12. Xanthophylls, pale yellow pigments and carotenes, deep yellow or reddish orange pigments.
- ⑪ 13. The fluid is largely water. Ions of mineral compounds, molecules of sugars and other soluble substances, and large molecules of proteins and other organic materials in colloidal suspension in the water form the content of the vacuole that is referred to as cell sap. Other vacuoles may contain food materials and waste products. Others serve as water-eliminating organelles in many one-celled organisms.
14. The cell wall is a double layer separated by a middle lamella composed of pectin. Cellulose forms the substance of the cell walls on either side of the middle lamella.
15. The cells of a tissue are similar in structure and in function.
16. A complete and entire living thing. It may be considered a fifth level of biological organization; however, there are organisms at all levels of organization.

ANSWERS TO APPLYING PRINCIPLES AND CONCEPTS (Page 69)

1. It is the simplest functioning unit containing the properties by which we recognize life. It is the unit comprising tissues and performing func-

- tions in the multicellular organism.
2. No, because the living condition involves more than a mere collection of chemicals. As far as we know now, all life comes from pre-existing life.
3. Various cell substances and organized bodies of the cells have different masses and densities—that is, they differ in size and weight. During high-speed centrifugation, centrifugal force separates them into different layers in the tube. The biologist may then remove material from any layer of the centrifuge tube and find a concentration of the specific cell materials he wishes to examine or analyze.
4. Radioautography is actually a form of photography. A substance normally taken in by cells is labeled with a radioactive isotope such as tritium. A slide bearing cells and the labeled substance is then treated with a photographic emulsion. After a time the slide is examined under a microscope, and the labeled substance appears as black dots. Thus if the substance has been taken into the nuclei of the cells, black dots will appear in the nuclei. The number of black dots indicates the amount taken up.
5. The nucleus contains DNA joined to protein molecules to form nucleoproteins. These molecules act as the genetic code of the organism. DNA synthesizes RNA which passes through the nuclear membrane and functions in protein synthesis in the cytoplasm. RNA is stored in the nucleolus.
6. The levels are cells, tissues, organs, organ systems, and organism. Each level increases in complexity and coordination and division of labor. This increase in complexity is considered to be a higher station of development than the less complex forms.

Guide to Laboratory Investigations for Chapter 4

INVESTIGATION 4-1

Study of Cells

Scope of the Investigation In this Investigation the student will study cells as Robert Hooke saw them (p. 55 of text) and study onion epidermal cells. As the student makes a microscopic study of the onion epidermal cells, he will see some of the cytoplasmic structures he studied on pp. 57-62. His study of the comparison of cork and onion epidermal cells should help him understand why Hooke was unable to see protoplasm. In his study of the mitochondria, he is studying the special organelles associated with the cell process of respiration (p. 57 of text).

Approximate time required One 50-60 minute period.

A Part 1 Study of Cork Cells

Suggestions for procedure. If students use a razor blade for cutting the cork, they should use extreme care, always making the cut away from themselves. It is easier to cut large corks. Emphasize that the cork must be cut very thin for this study.

Student observations—answers to questions.

- (a) No.
- (b) Yes.
- (c) No.
- (d) Cells are not living.
- (e) No.
- (f) Prevents loss of water and protects the cell from mechanical injury and protects the tree from invasion by bacteria and fungi.

A Part 2 Study of Onion Epidermal Cells

Suggestions for procedure. Caution the student to avoid wrinkling the thin transparent tissue because if he does he will have difficulty in locating a single layer of cells. In preparing the wet mount, the student should avoid using too much water. The drop of water should come to the edge of the cover glass. Caution the student not to tilt the microscope, as the liquid will run off his slide.

Emphasize that as he observes the onion epidermal cells under the microscope, he is looking at living cells with active protoplasm that Hooke did not see. There may be some movement in the cells, although in most there will not be. Have the student observe the cell content carefully as he adds the iodine stain to the cell. Point out that it is often necessary to stain cells in order to see the parts. Iodine is only one of many stains used for this purpose. As the student focuses up and down with his microscope to locate various organelles in the cell, his understanding of cell depth should increase, and he should become familiar with the various parts of the cell that are visible under the light microscope.

Student observations—answers to questions.

- (a) Rectangular with irregular outline.
- (b) Yes.
- (c) Grey.
- (d) Usually not.
- (e) Kills the protoplasmic structures.
- (f) The individual parts are more distinct.
- (g) Yellowish.
- (h) Yellowish to brownish.
- (i) No.
- (j) Yes.
- (k) Because different parts of the cell are in focus as the body tube is raised or lowered.
- (l) To store cell sap.

A Part 3 Observing Mitochondria

Suggestions for procedure. The preparation of the wet mount of celery for the study of mitochondria is a tedious job. The student may have to prepare several slides before he is successful. Emphasize that mitochondria are extremely small, and it is not possible to see them in all cells under the light microscope. Staining will help, but the stain will disappear rather quickly because of the presence of dehydrogenases. As the student observes these organelles, he should develop an understanding of why it has been difficult for the biologist to learn about specific functions of cell organelles such as mitochondria.

Student observations—answers to questions.

- (a) Answers will vary—probably not.
- (b) Answers will vary—probably a nucleus.
- (c) Answers will vary—should be a matter of minutes.

INVESTIGATION 4-2

Variation in Cell Structure

Scope of the Investigation This Investigation suggests several kinds of plant and animal cells for microscopic study. As the student examines these cells, he should

become aware of the presence of cell walls and the various plastids in plant cells discussed on pp. 61-62 of the text. The study of flower petal cells in Section 4 demonstrates the location of water-soluble pigments in vacuoles (pp. 62-63 of text). As he studies the epithelial cells he should also find many structures that he found in plant cells, but he should also find that animal cells lack the plastids and cell walls.

Approximate time required Most students will need 90 minutes to complete all Parts of this Investigation.

A Part 1 Examination of Various Cells

Suggestions for procedure. This Part is divided into four Sections so that the student may become familiar with many types of plant cells and the structure of an animal cell. Each student should do all Sections, since each one demonstrates the presence of specialized structures such as plastids, starch grains, and vacuoles.

The student should be told that the purpose of warming the elodea leaf is to stimulate the flow of cytoplasm in the cells. Since the leaf is several cells thick, have the student focus into the cell, not on the epidermis, to find a cell with streaming cytoplasm. This observation of living cytoplasm should be an exciting experience for the student. Have the student study the cell carefully to determine whether the chloroplasts are moving on their own or being carried in the cell cytoplasm. Emphasize that chloroplasts are green plastids found only in green plant cells. Have the students observe the thickness of the cell walls and point out that these walls serve to maintain the rigidity of the plant tissues.

Caution the student to prepare very thin slices of the potato. If a microtome is available, it is easier to use than a razor blade. The iodine stain is used to locate the starch grains. Point out to the student that these grains represent one type of food storage structure in plant cells. The student should avoid using too much iodine stain, since it often discolors the cells, making it difficult to distinguish the structures. Have the student study the walls to observe that they are thinner than in the cells of the elodea. Have the student examine the cells under low power, observing their relationship to each other before examining them under high power. The student will have difficulty in locating a nucleus, but the cytoplasmic threads are very distinct.

A study of the flower petal cells will further demonstrate the specialization of organelles in the cell. Point out that the color of many flowers is due to water-soluble anthocyanins contained in vacuoles. These will be visible in the flower petal cells that are studied.

An examination of the epithelial cells from the cheek will reveal the lack of a cell wall and plastids in animal cells. Caution the student to scrape the lining of the mouth gently to remove the cells. He will probably suggest that there is nothing on the toothpick. Point out that the cells are microscopic, and that it is not necessary for him to remove the lining of the mouth for study. Point out that methylene blue is another stain used to reveal structures that are not distinct in unstained materials. These cells should be studied in reduced light. The students will be able to distinguish the cytoplasmic granules, nucleus, and thin plasma membrane that bounds the cell. Frequently they may have the experience of seeing a cell in the process of dividing.

Student observations—answers to questions.

- (a) Probably.
- (b) Yes.
- (c) No.
- (d) They are being carried in the circulating cytoplasm.
- (e) Hexagonal in shape.
- (f) No.
- (g) Yes.
- (h) In starch grains.

- (i) No.
- (j) Probably not.
- (k) No.
- (l) Red and yellow ones.
- (m) No.
- (n) Yes, there are blue and purple pigments in the blue and purple flower petals. These pigments are found in vacuoles.
- (o) It is less rigid.
- (p) Plasma membrane.
- (q) Yes.
- (r) Broad and flat.
- (s) No.
- (t) Yes.

Chapter 5

The Cell and Its Environment

Having dealt with the life-producing chemical and physical properties of the cell, the student now turns to the environment in which the cell functions. Even though the environment of an organism is constantly changing, a steady state must be maintained in all its cells. This more constant environment within an organism provides water, nutritive elements, minerals, and oxygen necessary to maintain the cells in a living, functional condition. The same fluid bathing the cells removes metabolic wastes, carbon dioxide, and cellular secretions which may have a function elsewhere.

This chapter treats the ways in which these substances pass through the membrane on leaving or entering the cell. Passive transport by osmosis does not require energy, but active transport, which occurs when a particular cell concentrates a substance within its cytoplasm requires the expenditure of energy.

P. 70: The chapter begins with a definition and discussion of homeostasis. You may wish at this point to emphasize the importance of this steady state at every level of life by referring the student to other areas in the book in which it is treated (pp. 346-347 on stomate action; p. 646 on endocrine glands and feedback).

P. 71: In discussing the structure of the membrane you might compare it to the "skin" that forms on milk. That is, it is really an interface that forms at the boundary between a colloid and another material.

P. 73: In discussing diffusion you can open a can or beaker of ether (or peppermint oil, as some students find ether offensive) and ask for raised hands as each student begins to smell it.

P. 74: The potassium permanganate demonstration described here is also effective. Leave the jar out in the classroom and diffusion will be complete in a day or two.

Pp. 75-76: The thistle tube demonstration shown in Figs. 5-4 and 5-5 may be set up in the classroom and compared. In setting up the osmosis apparatus shown in Fig. 5-5, goldbeater's membrane or cellophane tubing may be substituted for sheep bladder. Some of the molasses will appear in the water, as the membrane is not completely impermeable to it. The force of gravity of the water column is comparable to the turgor pressure that finally stops osmosis in living cells.

In discussing water problems in animal cells you might ask what the problem of water balance is in salt-water organisms. Since the water concentration is lower outside these organisms, their problem is the opposite of that in fresh-water organisms: they must have ways of conserving water rather than eliminating it (see p. 709 for explanation).

P. 78: In discussing active transport, have the students examine Fig. 5-7 carefully, noting that because there is greater concentration of sodium ions outside the cell than inside, some force other than diffusion

must operate for sodium ions to enter the cell.

Suggested Films

Chemical Organization of a Cell (col, 28 min) AIBS McGraw-Hill

Diffusion and Osmosis (b&w&col, 11 min) Cor

MAJOR CONCEPTS

1. Living things maintain an intricate balance in the face of constantly changing conditions, both internal and external.
2. The life of a cell depends on the molecular traffic through the differentially permeable plasma membrane.
3. Diffusion is the spreading of a substance by molecular motion. Molecules move from a region of greater molecular concentration to one of lesser molecular concentration as the result of molecular collisions.
4. Osmosis is the diffusion of water through a differentially permeable membrane from a region of greater concentration of water to a region of lesser concentration of water. Therefore, salt water and fresh water affect cells differently.
5. Because of the rigid cell walls, osmosis causes turgor pressure in plant cells. Animal cells have water-eliminating mechanisms.
6. Alcohol and other solvents penetrate the cell more rapidly than water.
7. All ions do not penetrate the plasma membrane at the same rate.
8. Many cells receive or excrete molecules against a diffusion pressure that would normally cause movement in the opposite direction. This active transport requires the expenditure of energy by the cell.
9. Large molecules may be taken into a cell by pinocytosis.

ANSWERS TO QUESTIONS FOR REVIEW (Pages 79-80)

1. Homeostasis is a steady state, or balance, which organisms maintain by self-regulating adjustments. The steady state is necessary for the proper functioning of the cells.
2. Homeostasis occurs at all levels in the organization of living things. It involves adjustment of the entire

organism. Spiders, scorpions, lizards, and sidewinder rattlesnakes hide in burrows in the desert during the day and come out in the late evening or at night to seek food. The frog burrows in mud at the bottom of a pond to escape the cold of winter and the heat of summer. These survival adjustments are self-regulating homeostatic devices. The cells and tissues of the frog could not survive either temperature extreme.

In higher animals we find continuous homeostatic adjustments at the organ and system level. Organs function in close association with other organs in maintaining an optimum internal environment. On the tissue level there is a precarious homeostatic regulation of the body fluids that bathe cells and provide the immediate internal environment.

On and in the lakes and streams, oceans and seas, live many one-celled and simple colonial organisms. Here the single cells or groups of cells adjust to extreme environmental changes.

3. If a substance passes through a membrane, we say that the membrane is permeable to that substance. Membranes that vary in the rate and degree of penetration of various substances are said to be differentially permeable.
4. Diffusion is the spreading of a substance by molecular motion. Molecular movement occurs in gases, liquids, and to a lesser extent in solids. The force of collisions causes molecules to spread apart from one another and distribute evenly in a given area.
5. When all molecules of a diffusing gas are distributed equally among the air molecules, diffusion stops. A state of equilibrium exists.
6. The higher the temperature, the greater the speed of molecular movement, and thus the faster the diffusion. The converse is true with lower temperatures. The higher the pressure, the greater the speed of molecular movement, and thus the faster the diffusion. Thus, diffusion

- occurs from an area of higher temperature to one of lower temperature, and from a region of higher pressure to one of lower pressure.
7. Differences in molecular concentration, temperature, and pressure affect diffusion. The force resulting from these differences is called diffusion pressure.
 8. Osmosis is the diffusion of water through a semipermeable membrane from a region of greater concentration of water to a region of lesser concentration.
 9. Turgor is the pressure that builds up in a cell as the result of water diffusing into the cell.
 10. No, because there would be diffusion of molecules into and out of the cell until equilibrium was reached, and no pressure would be built up.
 11. Animal cells lack the supporting structure of a cell wall, and would burst if turgor pressure were built up.
 12. Water diffuses into the cell causing its membrane to bulge, and the cell swells until it bursts.
 13. Many one-celled organisms, living in a fresh-water environment, are equipped with special water-eliminating organelles known as contractile vacuoles. Fish and other gill-breathing aquatic animals take in large amounts of water with the oxygen they absorb into the blood. These animals excrete excess water in the urine. Our kidneys, sweat glands, and lungs eliminate excess water and prevent our cells from receiving too much water.
 14. Plasmolysis is the loss of turgor. Since the direction of water diffusion is determined by differences in the concentration of water inside and outside the cell, the cell will lose water when placed in a solution of lesser water concentration. This results in loss of turgor pressure and shrinking of the cell content. In a

plant cell, the membrane may be seen to shrink away from the cell wall.

15. These substances penetrate a cell membrane rapidly because it is believed that they dissolve the fat layer of the membrane.
16. During active transport, certain ions may accumulate in a cell. Cellular energy is used in transporting these substances through the membrane.
17. Large molecules cannot pass through the pores of a membrane and into a cell. It is believed that they flow into indentations of the membrane and are sealed off as the membrane closes behind them. The material is then enclosed in a membrane within the cell as a vacuole. This engulfing process is referred to as pinocytosis.

ANSWERS TO APPLYING PRINCIPLES AND CONCEPTS (Page 80)

1. Answers will vary but involve adjustments to temperature, salinity of water, and mineral concentration.
2. Pinocytosis is not dependent on the size of pores in a membrane.
3. If the surrounding solutions had a higher solute concentration, water molecules, which are essential to the life of the cell, would leave the cell and it would die.
4. The cells of a fresh-water plant would lose turgor as water passed out of the cells and plasmolysis occurred. The cells would not be able to carry on their normal activity and would die. The cells of a salt-water plant would increase in turgor if placed in fresh water. This would interfere with the normal movement of substances into and out of the cells.
5. Cells that are engaged in active transport have been observed to respire at a greater rate. Since the consumption of oxygen varies proportionately with the amount of energy consumed, it is believed that active transport requires the use of energy by the cell.

Guide to Laboratory Investigations for Chapter 5

INVESTIGATION 5-1

Principles of Diffusion

Scope of the Investigation This Investigation bears out the discussion of diffusion of molecules on pp. 73-74 of the text. The student has the actual experience of studying diffusion of gases, liquids, and a solid into a liquid. The student should develop a concept of why the composition of the air remains constant after he has studied the diffusion of peppermint oil or perfume in Section 1. His observation of diffusion of sugar in water and potassium permanganate crystals in water should result in an understanding of the variation in the rate of diffusion in different states of matter. When he has compared the rate of diffusion of the molecules of the various states of matter, he should relate the behavior of the molecules to their kinetic energy (p. 33 of text).

Approximate time required Students in the classroom should be able to detect the peppermint oil or perfume within 5 minutes. The diffusion of liquids (molasses and water) in Section 2 will require approximately 10 minutes. The initial diffusion of the potassium permanganate can be detected in a few minutes, but complete diffusion will require about 20 minutes.

A Part 1 Diffusion of Gases, Liquids, and Solids

Suggestions for procedure. The peppermint oil or perfume should be strong enough that students in the back of the room can detect the odor when the molecules have diffused into that area. Keep the windows and doors closed during the course of this experiment. Warn the students that some of them may not detect the odor because of colds or poor olfactory sense. Emphasize that the molecules are more concentrated in the evaporating dish, resulting in diffusion of the peppermint oil or perfume into the air. Point out that there is also diffusion of air molecules into the dish. When the concentration of peppermint oil or perfume molecules in the air is uniform, diffusion ceases.

The student should observe that the rate of liquid diffusion of the sugar is slower than that of gaseous diffusion. Point out that this is because of the fact that the molecules of the sugar are closer together and have less kinetic energy than the gaseous molecules. Have the student watch the direction of flow of the sugar into the liquid medium.

Do not put too many potassium permanganate crystals into the beaker, since diffusion is slow because the molecules of the crystal are close together and have relatively little kinetic energy. Have the student note carefully the flow of the color as the crystals are dissolved by the water.

Point out to the students that the molecules of gas, sugar, and potassium permanganate are actually carried in two ways. They move by their own kinetic energy, which is an example of diffusion. In addition, many molecules flow in the same direction, as observed in the diffusion of the sugar in water and of the potassium permanganate in water. This is referred to as mass flow.

Student observations—answers to questions.

- (a) Answers will vary (should detect the odor first).
- (b) Answers will vary (should detect odor later than the student nearest the dish).
- (c) Probably not.
- (d) The molecules of peppermint oil or perfume are more concentrated in the dish than in the room.

- (e) Until a state of equilibrium is reached.
- (f) No.
- (g) Molecules of air are also moving into the dish.
- (h) Some students have a keener sense of smell than others.
- (i) The oxygen in the lower level of the atmosphere must diffuse upward to supply the organisms living there with oxygen.
- (j) Yes.
- (k) Yes.
- (l) It becomes sweeter as time passes.
- (m) It is slower than that of gases.
- (n) Upward.
- (o) No.
- (p) Yes.
- (q) Very little, if any.

INVESTIGATION 5-2

Diffusion and Osmosis

Scope of the Investigation In this Investigation the student will perform several experiments that should increase his understanding of diffusion and osmosis that he studied on pp. 74-76 of the text. The concept of permeable membranes is demonstrated in the simple diffusion experiment with the muslin separating the molasses and water that will mix, and in which a state of equilibrium can be reached (p. 74 of the text). Differentially permeable membranes are introduced in the second experiment in which an osmosis membrane separates the molasses and water. The principle of differentially permeable membranes is demonstrated when the water passes freely through the membrane into the molasses, but the sugar molecules fail to diffuse into the water, resulting in a rise of the molasses solution in the thistle tube. The study of osmosis through the egg membrane in Part 2 introduces the manner in which water enters the cells of living things.

Approximate time required Several students may work simultaneously to set up the osmosis demonstrations with the thistle tubes and the osmosis demonstration using an egg. It will take approximately 30 minutes to set up each of the demonstrations. The demonstrations should extend over two or three days.

A Part 1 Diffusion Across Membranes

Suggestions for procedure. Two students will be required for each of the osmosis demonstrations. One is needed to fill the thistle tube with the molasses and the second one to put the muslin or osmosis membrane over the bulb. Be sure to have a student soak the osmosis membrane for a few minutes to make it pliable. Each of the membranes must be tied securely to prevent the molasses from seeping out into the water. Assign a student to check each of the demonstrations, marking the level of the molasses at the start of the demonstration and twice a day for 24 or 48 hours. Point out that two factors are controlling the movement of the sugar molecules and water: the kind of membrane involved and the diffusion pressure of the water. The student should observe that the muslin permits movement of molecules of sugar and water, but the osmosis membrane permits only the water molecules to pass through it. Emphasize that the two-way movement of the sugar molecules and water through the muslin continues until a state of equilibrium is reached. The water molecules will continue to enter the molasses solution and the column will rise until the weight of the solution in the thistle tube is equal to the diffusion pressure of the water molecules.

Student observations—answers to questions.

- (a) Battery jar.
- (b) Thistle tube A.
- (c) Yes.
- (d) Yes.
- (e) Yes.
- (f) No.
- (g) The water in battery jar A was discolored by the molasses.
- (h) No.
- (i) No.
- (j) Yes.
- (k) No.
- (l) The water and sugar molecules are equally dispersed on both sides of the muslin.
- (m) Diffusion occurred in both directions in battery jar A, but in battery jar B only the water molecules diffuse through the differentially permeable membrane, resulting in the rise of the molasses solution in the thistle tube.
- (n) The force of the molasses solution was equal to the diffusion pressure of water molecules.
- (o) Muslin is permeable to both the sugar and water molecules, but the osmosis membrane is permeable to water molecules only.
- (p) During osmosis, water molecules diffuse through a differentially permeable membrane from a region of greater concentration to a region of lesser concentration.

B Part 2 Osmosis Demonstration Using an Egg

Suggestions for procedure. This Part should be set up as a demonstration. Be sure that the student locates the air cell in the rounded end of the egg before he begins to remove the shell to expose the egg membrane. Caution him to use extreme care in chipping the small pieces or he may rupture the membrane. If the hydrochloric acid is used to soak the rounded end, put the acid in an evaporating dish and support the egg on a triangle so that only the end is submerged in the acid. The egg should not be left too long, and the student should use extreme care with the acid. The hole in the other end of the egg should be just large enough to insert the glass tubing. Caution the student to use care in inserting the tube or he will crack the egg. The end of the tube should be lowered just inside the shell. Caution the student to make a firm seal with the paraffin or water will flow into the egg and the demonstration will fail.

Assign a student to check the setup, marking the level at the beginning of the experiment and each time it is checked. If the egg content is rising too quickly, it may be necessary to add a section of tubing as described in the student manual. Emphasize that the exposed membrane of the egg in the water is a model of a membrane of a living cell. The student should conclude that water passes freely into living cells according to the laws of diffusion, but that cell contents do not diffuse through the membranes.

Student observations—answers to questions.

- (a) Answers will vary.
- (b) Water molecules were more concentrated outside the egg than inside.
- (c) When the force of the pressure of the egg contents equaled the diffusion pressure of the water molecules.

Interpretation. The shell membrane of the egg is permeable to water molecules but is not permeable to the egg contents. Since the water molecules were more concentrated outside the egg membrane than inside, the water molecules diffused into the egg until the pressure inside created a force equal to the diffusion pressure outside.

INVESTIGATION 5-3

Diffusion Through Cell Membranes

Scope of the Investigation This Investigation bears out the discussion of diffusion through membranes on p. 75 of the text as the student actually sees materials pass into and out of cells. The selectivity of living membranes and loss of the control of molecular movement in killed membranes is demonstrated. The student should gain a graphic understanding of osmosis, which he has studied on pp. 75-76 of the text, particularly when he observes plasmolysis in a salt solution. If any students do the C-level Part, they will learn about water elimination by contractile vacuoles in paramecia (p. 76 of text).

Approximate time required Most students should complete the observations in Parts 1 and 2 in 50-60 minutes. Time may be saved by putting the potato slices in the salt solution and in water while Part 1 is in progress. Students may also boil the beet slices used in Part 2 while Part 1 is in progress.

Part 3 will require five days but may be correlated with other laboratory work. The student should put the eggs in hydrochloric acid at the beginning of the first laboratory period and inspect the eggs several times during the period. It may be necessary to leave the eggs in the acid for several hours. Periodic inspections of the shell should be made by the student (as his class schedule permits) or by the teacher.

Part 4 will require anywhere from two to five hours of work.

A Part 1 Diffusion Through Living Membranes

Suggestions for procedure. The elodea should be a vigorously growing plant. If elodea is not available, cells of an alga such as *Spirogyra* may be substituted. Petunia or lobelia flower petals are suggested in Section 3, although other blue or purple flower petals may be substituted. However, the petals used should demonstrate a color change in the presence of an acid or a base.

It is important that the student watch closely for changes in the content of elodea cells as the salt and sugar solutions are added. Loss of cell turgor and resulting plasmolysis will be clearly demonstrated as water diffuses from the cell into the hypertonic salt and sugar solutions. The addition of distilled water to the cells plasmolyzed in salt solutions should restore much of the cell turgor. The student should remove as much of the salt solution as possible before adding the distilled water.

The diffusion of water out of the potato cells into the concentrated salt solution results in loss of turgor and a flaccid condition of the potato. The cells of the freshly cut potato slices also lose some water to the atmosphere, resulting in a loss of turgor. However, the slices are less limp than those in the salt solution. The increase in turgor pressure in the cells is demonstrated in the crisp condition of the potato slices in the water.

Color changes in the cells of flower petals are usually rapid, since the H^+ ions of the hydrochloric acid and the OH^- ions of the ammonium hydroxide diffuse through the cell membranes rapidly. The distilled water serves largely as a control, in which no color change occurs. There may be an increase in the cell turgidity, however.

Student observations—answers to questions.

- (a) The cell membrane is pressed firmly against the wall; the chloroplasts are dispersed through the cytoplasm.
- (b) 3-5 drops.
- (c) The cell content and its surrounding cell membrane, which was pulled away from the cell wall, shrank into a mass in the center of the cell.

- (d) Out of the cell.
- (e) The salt solution, with a lower water concentration than that of the cell content.
- (f) Student answers will vary, depending on the amount of remaining salt solution and extent of cell plasmolysis. However, the cells should regain turgor and may even bulge slightly.
- (g) Potato slices are rather soft and somewhat limp.
- (h) Potato slices are crisp and firm.
- (i) Increased.
- (j) Water entered the cells, creating turgor pressure.
- (k) Potato slices are soft and limp.
- (l) Softer and more limp.
- (m) Lost.
- (n) Water concentration of salt solution was less than that of the potato cells, resulting in the diffusion of water from the cells to the salt solution.
- (o) No change occurs in the pigment in the plastids. Turgidity of the cells may increase.
- (p) The pigment (anthocyanin) in the plastids changes to reddish pink.
- (q) The pigment turns blue.
- (r) The ions of the acid and base diffused into the cells to cause the color change.

A Part 2 Diffusion Through Killed Membranes

Suggestions for procedure. The purpose in washing the beets is to remove the pigment and other content from the cells cut in slicing. If the slices are washed thoroughly, any pigment that appears in the water must have diffused through the cell membranes.

It will be necessary to examine the yeast cells in Section 2 closely under high power of the microscope to detect the presence of Congo red in the wall only of living cells but in the cell content of killed cells.

Student observations—answers to questions.

- (a) The water is clear or only slightly reddish.
- (b) The water is deep red.
- (c) The living cell membranes in the slices in cold water retained the pigment molecules. However, the pigment molecules diffused into the water in the heat-killed membranes of the boiled beet slices.
- (d) The walls appear red or pink. The cell contents are unstained.
- (e) The cells have absorbed the stain and appear red or pink.
- (f) Molecules of stain penetrated the wall but did not pass through the membranes of unboiled yeast cells. However, molecules of stain passed freely through the membranes of heat-killed cells and penetrated the cell substance.

B Part 3 Diffusion Through the Membrane of an Egg

Suggestions for procedure. The removal of the shell from the eggs by dissolving in acid is not a difficult procedure, but must be done carefully. The egg will be ready for use when it is pliable. Care must be used to avoid rupturing the shell membrane. If the dissolving of the shell is finished at a time when the class is not in session, the egg should be placed in a plastic bag and stored in a refrigerator for use. Caution the students against spilling acid while examining the egg. The measurements of the volume of the egg at the start of the experiment and on four consecutive days is by water displacement. This will require accurate measurement of the displaced water in a graduated cylinder.

Interpretation. The egg in distilled water should increase in volume each of the four days during which measurements are made. By the end of the second day, the egg may

increase to twice the original volume, due to passage of water molecules from the distilled water into the content of the egg. In the 15% salt solution, the volume of the egg should decrease each day as water molecules diffuse from the egg content to the hypotonic external salt solution. Water loss from the egg may reduce its volume to one-half the original volume. At the close of the experiment the egg in salt water should appear shriveled. The student should relate diffusion of water molecules to appearance of the egg in distilled water and 15% salt solution in interpreting the results of this Part of the Investigation. He should also apply these results to what he has learned about osmosis.

C Part 4 Water Balance in a One-celled Organism

Suggestions for procedure. The student may culture his own paramecia using culture media available from biological supply companies and adding organisms he has obtained in the “wild state” or he may be supplied a pure culture of *Paramecium caudatum* or *Paramecium multimicronucleatum* from a supply company. Either culture should contain many organisms of the same species. Other apparatus and materials are standard laboratory equipment except for the micropipette, which can be made by heating glass tubing and drawing it to a fine tip. A stop watch will be valuable in timing the interval between contractions of the contractile vacuole, although a watch with a second hand will suffice.

The student should determine the interval between contractions of the contractile vacuole by examining several paramecia in the water taken from the culture. This rate should be based on at least 10 determinations and perhaps 10 different specimens. This will establish an average and determine the extent to which contractions are constant in a species in a given environmental situation.

Previous studies of paramecia have indicated that the interval between contractions of the contractile vacuole is between 3 and 5 seconds. If the student has opportunity to observe the rate of contraction of the vacuoles under different amounts of activity, he should find that the rate of contraction is relatively constant and not related to activity of the organism.

In preparing salt solutions of varying concentrations, all percentage solutions should be made up on a weight basis. For example, a 0.25% NaCl solution should contain 0.25 gm NaCl to 100 gms (ml) of distilled water. The concentration of solutions external to the cell influence the rate of contraction of the vacuoles. As the concentration of sodium chloride increases, the interval between contractions also increases. Investigators have found these approximate results in using the sodium chloride concentrations recommended in this Investigation:

Percent NaCl in water	0.0	0.25	0.5	0.75	1.00
Contraction period in seconds	6	9	18	25	163

Analysis and conclusions. The student may devise various methods for presenting his experimental data. The contraction intervals in a single organism and in several organisms may be shown in a table. Contraction rates in various concentrations of sodium chloride in aqueous solutions are graphically shown in a line graph. In his conclusions, the student should account for his results in terms of water diffusion in relation to hypotonic and hypertonic solutions external to the cell.

Chapter 6

Cell Nutrition

This chapter provides information basic to the understanding of energy relationships. Since the energy for life as we know it on the earth comes ultimately from the sun, we should have some knowledge regarding the method by which this energy is made available to us. The tools and methods by which we have learned about photosynthesis are discussed and provide a background which makes the process of photosynthesis logical and easier to understand. The importance and use of isotopes of oxygen and carbon are explained.

Photosynthesis begins when light energizes chlorophyll *a*, causing water molecules to be split into hydrogen and oxygen. At the same time ATP is formed from ADP in the chloroplasts, thus converting light energy into chemical energy. Although the remainder of the chemical activity during photosynthesis normally occurs in the light, it should be pointed out that it is called the "dark" reaction because light is not necessary. During this phase of photosynthesis carbon is fixed in the form of carbohydrates.

The process of chemosynthesis and the similarities between it and photosynthesis are next explained; the major difference is that in chemosynthesis inorganic chemical reactions rather than light are the primary source of energy.

Individual study may be provided by reports and library research on the fascinating story of the scientists who contributed to our knowledge of photosynthesis. The student interested in physics may find an interest in reading and reporting on the pigments and spectrum used by a various plants for their primary energy source.

P. 83, left column: Call attention to Fig. 10-13 on p. 147, which shows the effect on a plant of a lethal gene which prevents the plant from developing chlorophyll.

P. 84: Compare the nature of photosynthesis with respiration and the importance of both to man.

P. 89, right column: We have already referred to the use of artificial light in plant raising. This is important in green-

houses, where flowers must be brought into bloom for special seasons. Interestingly enough, cutting down the amount of light may also stimulate bloom. A good example of this is the chrysanthemum, which normally blooms during shorter fall days. These flowers are brought into bloom out of season in the greenhouse by cutting down the light.

P. 91, right column: Parasites and saprophytes are nutritionally dependent.

P. 91, Fig. 6-10: The practical application of this diagram is to illustrate how man depends on the conversion of raw material by the plant into other substances, i.e., nuts have a high oil content, cereal grains like corn have a high starch content, fiber plants like flax have a high cellulose content.

Suggested Films

Photosynthesis: Chemistry of Foodmaking (b&w&col, 13½ min) Cor

Patterns of Energy Transfer (col, 28 min) AIBS McGraw-Hill

MAJOR CONCEPTS

1. Cellular energy is derived from the breaking of chemical bonds in complex molecules. ATP is an important energy compound stored by cells.
2. Cellular structures are constantly changing. Growth and repair is a continuous process in a living cell.
3. Chlorophyll-containing grana constitute the machinery of photosynthesis.
4. Four different types of chlorophyll are found in various plant cells; the most abundant and important being chlorophyll *a*. Other chlorophylls absorb light energy and transfer it to chlorophyll *a*.
5. During photosynthesis light energy is used by green plants to combine carbon dioxide and water in the formation of glucose and in releasing oxygen, but many steps are involved. Although the first stage occurs in the light, the second stage of chemical reactions, the synthetic phase, may occur in the dark.

6. Certain bacteria organize carbohydrates without using light energy by a process known as chemosynthesis, as they possess enzyme systems capable of trapping energy released during inorganic chemical reactions.

ANSWERS TO QUESTIONS FOR REVIEW (Pages 92-93)

1. Since energy does not cycle, organisms must be provided with new energy to replace that which is used in maintaining the living condition.
2. Chlorophyll molecules are embedded partially in the protein disks of the grana and partially in the fatlike layers between them.
3. a. Chlorophyll *a*—most abundant and important in photosynthesis; b. chlorophyll *b*—a yellow-green pigment; chloroplasts in the cells of seed plants usually contain both these chlorophylls in the approximate ratio of three parts chlorophyll *a* to one part of chlorophyll *b*; c. chlorophyll *a* and *c*—in brown algae; d. chlorophyll *a* and *d*—in red algae; e. bacteriochlorophyll—in granules of purple sulfur bacteria.
4. *Chlorella*, a microscopic alga, can be grown in large numbers easily, can be killed rapidly, and can be grown in a variety of media.
5. When chlorophyll receives the light, it is believed that a sudden change occurs in the molecules themselves. Electrons move to shells farther away from their nuclei, and consequently from lower to higher energy levels. This converts light energy to potential chemical energy, which is used in splitting water molecules and in converting ADP to ATP.
6. *Chlorella* cells were grown in water containing heavy oxygen (H_2O^{18}) and it was found that the oxygen released during photosynthesis was O^{18} .
7. When ADP is converted to ATP, more energy is stored for use in photosynthesis. Energy remains in the ATP molecule as long as the extra phosphate group is attached. Chemical removal of the phosphate

releases the energy and reforms ADP. Much of this energy stored in ADP is used in the dark reaction.

8. TPN is a coenzyme which receives the hydrogen as it is split from the water molecule during the first phases of photosynthesis. This forms TPNH_2 and soon passes the hydrogen on to another compound.
9. RDP, a 5-carbon sugar, is the carbon dioxide acceptor in the chloroplast. When it combines with CO_2 it forms a 6-carbon sugar which is very unstable and breaks down to form 2 molecules of PGA.
10. PGA receives hydrogen from TPNH_2 to form PGAL. The high amount of energy required to form PGAL is supplied by the conversion of ATP to ADP. PGAL can be used directly by the plant or it can be converted to other compounds for storage.
11. a. RDP (ribulose diphosphate); b. glucose; c. fructose; d. sucrose; e. maltose; f. starches and cellulose; g. oils.
12. In photosynthesis the energy comes from the sun; in chemosynthesis the energy comes from an inorganic chemical reaction.

ANSWERS TO APPLYING PRINCIPLES AND CONCEPTS (Page 93)

1. Whenever a phosphate group is removed from an ATP molecule, energy is released and the molecule returns to a state of lower energy—ADP. The ADP resembles a low bank balance to which another high-energy phosphate may be added to return it to ATP.
2. Ribulose diphosphate is a 5-carbon sugar molecule to which two phosphate groups are attached. It receives the CO_2 from the air and forms a 6-carbon sugar which is very unstable, splitting into two molecules of PGA (phosphoglyceric acid). PGA is the first stable product of photosynthesis and has been recovered from photosynthetic studies using *Chlorella*.
3. *Autotroph* refers to the capability of organisms to organize organic mole-

cules—thus the photosynthetic and chemosynthetic organisms. Heterotrophs are animals and nongreen plants such as fungi that are nutritionally dependent organisms. Were it

not for photosynthesis the life of our earth would probably be limited to a few bacteria. There would be no forests or grasslands and no animal populations.

Guide to Laboratory Investigations for Chapter 6

INVESTIGATION 6-1

Characteristics and Composition of Chlorophyll

Scope of the Investigation Several properties of chlorophyll are demonstrated in this Investigation. The student will discover that chlorophyll is soluble in boiling alcohol, but not in water. The demonstration of fluorescence bears out the discussion of how chlorophyll serves as an energy carrier on pp. 86-87 of the text. The separation of the dark-green pigments from the yellow-green pigments provides evidence that the chlorophyll solution contains more than one pigment and that the pigments are differentially soluble.

The technique of paper chromatography is a simple and striking way to analyze a chlorophyll solution. Study of the chromatogram shows that each pigment does not occur in the same proportion in the leaf.

If any students do the C-level, they will learn about the amount of energy absorbed from the various wavelengths of the visible spectrum (pp. 89-90 of text).

Approximate time required Part 1 will require 40 minutes. Since the chlorophyll solution used in Part 2 was prepared in Part 1, the student can complete the column chromatography technique in 50-60 minutes. The disk chromatography technique is easy and can be completed in 20 minutes.

Part 3 may require several days since the student must become familiar with the spectroscope and the color bands of the visible spectrum in white light before he can study absorption by chlorophyll. The preparation of a chlorophyll solution will require 10 minutes. After the student has learned to use the spectroscope, he may complete his study of the absorption of light by the chlorophyll solution in 50-60 minutes.

A Part 1 Extraction and Testing of Chlorophyll

Suggestions for procedure. Any type of leaf may be used for chlorophyll extraction. Geranium and begonia have been suggested because they are usually available in the laboratory. Frozen spinach also works well.

In order for the alcohol to dissolve the chlorophyll, it must be boiling. The beaker containing the alcohol must be set in a water bath or pan of water, as alcohol is flammable and should never be heated over an open flame. It is well to have a carbon dioxide fire extinguisher in the laboratory to smother the fire if one should get started. Water is never used to extinguish an alcohol flame.

If the chlorophyll solution is not clear, it may be necessary to filter it to remove any suspended material that might alter the results. Point out to the student that the chlorophyll is green because it reflects the green portion of the visible spectrum.

For the best results in the study of fluorescence, the chlorophyll solution should be put in a bottle with flat sides. Refraction bottles or small, four-sided druggist's bottles can be used. If these are not available, culture tubes (1 to 1¼ inches in diameter) will work. Wrap the sides and bottom of the culture tubes with black masking tape, so that there is a thin vertical slit on one side. Direct the light through the slit and observe the solution from above. Any study of fluorescence is best observed in a dark room. The

result of the comparison of the ability of food coloring to fluoresce with that of chlorophyll provides additional evidence that the energy of fluorescence may be involved in energy transfers in photosynthesis.

Differential solubility is demonstrated in the separation of the yellow green and dark green pigments, the yellow green being more soluble in alcohol and the green in carbon tetrachloride. Warn students not to inhale the poisonous carbon tetrachloride fumes and to avoid spilling any of the liquid on their skin.

Student observations—answers to questions.

- (a) No.
- (b) Chlorophyll is not soluble in water.
- (c) Yes.
- (d) Chlorophyll is soluble in alcohol.
- (e) Red color.
- (f) Fluorescence.
- (g) Green.
- (h) Green food coloring does not fluoresce.
- (i) There are two layers of solution; the upper one is yellow, the lower one is dark green.
- (j) Yellow.
- (k) Green.

B Part 2 Separation of Chlorophyll Extract by Paper Chromatography

Suggestions for procedure. In the column chromatography, the filter paper should extend into the acetone about $\frac{1}{4}$ inch. This will permit the acetone to move up the paper by capillary action. Point out that the acetone carries the chlorophyll pigments with it, and that they will separate as they move up the filter paper. The fine-tipped pipette can be made by drawing out a piece of capillary tubing. A short piece of rubber tubing can be put over the end so that the student can draw up the chlorophyll solution. The line made by the chlorophyll solution should be almost black. This is necessary since there must be sufficient material on the paper to produce the chromatogram. Be sure that the stopper is inserted tightly in the test tube because the solvents being used are volatile.

The separation of the plant pigments must be watched carefully until the solvent has almost reached the top. Since the solvent evaporates rapidly and the pigments are often unstable, fading or changing color, the point to which the solvent flowed and the location and identification of each pigment must be made immediately.

The separation of pigments in the disk method must also be identified immediately. These will occur in rings around the filter paper. Five distinct color zones will probably be found from top to bottom on the strip or from outer ring to the inner ring on the disk. These will be yellow-orange, yellow-green, light-green, dark-green, and blue-green. The yellow-orange is the carotene, the yellow-greens are xanthophyll I and II, the dark green is chlorophyll *a*, and the blue-green is chlorophyll *b*. The chlorophyll pigments separate out first. Students should conclude that these pigments are more soluble than the xanthophylls and carotenes.

Student observations—answers to questions.

- (a) Could have as many as five rings.
- (b) Yellow-orange, yellow-green, light green, dark green, blue-green.
- (c) Probably not.

Interpretation. Paper chromatography is a simple method of analyzing chemical composition utilizing the principles of capillarity and differential solubility. For example, the technique clearly reveals five pigments present in green leaves.

C Part 3 Absorption of Light by a Chlorophyll Solution

Suggestions for procedure. It will be necessary for the student to become skilled in the use of the spectroscope. He should become acquainted with the width of the color bands of the visible spectrum and the relative absorption of these by a white light before attempting a study of the absorption of visible light waves by the chlorophyll solution.

The student should prepare a fresh solution of chlorophyll for his study if the one prepared in Part 1 has been exposed to light for any length of time, as light alters the composition of the chlorophyll.

Analysis and conclusions. The examination of the absorption of light rays of the visible spectrum will be relative unless the spectroscope is calibrated in millimicrons. The results of the study may be plotted on a graph and as a table.

The student should relate the degree of absorption of the various wavelengths to the energy required for photosynthesis. The violet and blue rays should show the greatest degree of absorption, followed by the red and orange rays, with the yellow and green showing the least degree of absorption.

INVESTIGATION 6-2

Photosynthesis

Scope of the Investigation As the student performs Part 1 of this Investigation, he will observe how carbon dioxide and light energy are necessary to the photosynthetic process that he studied on pp. 82-90 of the text. The presence of starch in the leaves of the plants used in the controlled environment studies serves as an indicator that photosynthesis has occurred.

The student actually observes that oxygen is a by-product of photosynthesis (p. 84 of text) as he studies the emission of oxygen bubbles from the elodea and collects and tests for the presence of oxygen in the glass tubing.

A study of the glucose content of various kinds of leaves demonstrates that all plants do not produce the same amount of glucose during photosynthesis.

The student actually observes that light and temperature are important factors in the control of photosynthesis (pp. 89-90 of the text) in their study of the elodea plants held under different light conditions and at different temperatures.

Approximate time required The preparation of the setup for Part 1 will require 10 minutes if one student is assigned to prepare one of the containers. This is best done as a group project or demonstration. The experiment will run for 48 hours, and the starch test for each leaf will require 15 minutes. Again, each member of the group can be responsible for testing one leaf.

Part 2 can be set up as a demonstration or by groups of students. The preparation of the setup will require 15 minutes. This can be done by a student or group of students while others are responsible for the setup in Part 1. The actual experiment will run for several days. There should be at least one inch of gas in the tube before the student tests for the presence of oxygen. The actual test will require no more than five minutes.

Part 3 will require approximately 20 minutes to complete. Students may test several kinds of leaves and combine their results.

The setup for Part 4 will require 5 minutes, but the tubes will be left under the various light conditions for 15 minutes. These tubes might be placed in their respective environments before the student begins the experimental part of Part 3. Timing will depend on the period length. Again, this is best suited to a group activity. A great deal

of time can be saved by having several students working simultaneously on this Part. The counting of the bubbles given off by the elodea sprig will require at least 10 minutes, although they are counting for only 6 minutes.

The test for the effect of temperature will require 20 minutes for counting, but approximately 40 to allow for the temperature changes. This time can be reduced if four students are assigned to investigate the effect of the various temperatures on the four plants.

Part 5 is a long-range investigation extending over a period of a week. This is also best suited to group study. The wrapping of each plant will require 10 minutes. The iodine test at the end of the week will require 15 minutes per leaf. Other laboratory studies are to run concurrently with this Part.

A Part 1 Demonstration to Show that Light and Carbon Dioxide Are Required for Photosynthesis

Suggestions for procedure. The leaves of the geranium or coleus plants should be green, not variegated, and should be taken from the most actively growing part of the plant. The petiole of the leaf should be long enough that the leaf will not touch the water or reagent. The student may add the reagent before putting the small container with the leaf in it into the larger container. Caution the student that the level of the reagent will rise when he puts the small container in, and he must be careful not to fill the larger container too full.

Point out to the student that the baking soda will provide the carbon dioxide necessary to the leaf. It is not necessary to go into the chemistry of the reaction. If possible, expose the leaves in jars 1 and 2 to a light source for 48 hours. The jars might be placed in a storage room with an overhead light for the duration of the experiment.

The technique for removing the chlorophyll and caution in using boiling alcohol have already been discussed in Investigation 3-4. Point out that the same technique used for testing for starch in organic nutrients is also used here. As he observes the color changes in the leaf in jar 1 and none in jars 2, 3, and 4, the student should become aware of the factor or factors necessary for photosynthesis that were missing.

Student observations—answers to questions.

- (a) Green color of the chlorophyll masks the reaction.

A Demonstration to Show That Oxygen is Given Off During Photosynthesis

Suggestions for procedure. The water plants such as elodea that are used in this Part should be young and healthy for the best results. Since the student is collecting oxygen in the glass tubing, he should make sure there is no air in the tube at the beginning of the experiment. Have the student place the setup in a sunny place. He should study the experiment periodically to observe that oxygen bubbles are being emitted from the base of the cut stem. The burning of the glowing splint in the gas at the conclusion of the experiment is evidence that oxygen is a by-product of photosynthesis, since it could not have come from any place other than from the elodea.

Student observations—answers to questions.

- (a) Light energy is essential to photosynthesis.
- (b) Light energy is released from the energized chlorophyll to supply the force necessary to break the bonds that hold the atoms of the water molecule together.
- (c) The splint begins to burn as it bursts into flame.
- (d) The elodea.

A Part 3 Demonstration to Show That Glucose is Produced in a Green Leaf

Suggestions for procedure. Students should grind only one kind of leaf at a time, washing the mortar before grinding a second kind of leaf. The tube should not contain more than one-quarter inch of the chlorophyll material. Caution the students to add the Fehling's solution A and B slowly so that the tube is no more than one-half full. If it is too full, it may boil over and burn the student. Caution the student to hold the tube erect while it is boiling; this avoids spilling of the hot contents. Emphasize that the results are interpreted in terms of degree of color. If the material is yellow, the leaf has produced very little glucose. If it is brick-red, the leaf has produced a large quantity of glucose. Glucose content of leaves from trees of a single genus will provide interesting results, probably varying a great deal in the production of glucose.

Student observations—answers to questions.

- (a) Should show some degree of sugar production.
- (b) Probably not.
- (c) Amount of glucose in the leaf will be related to chlorophyll production, light, temperature, and carbon dioxide available.

B Part 4 Measuring the Rate of Photosynthesis Under Varying Environmental Conditions

Suggestions for procedure. This Part should be done as a group demonstration. It is best for the teacher to cut the sprigs of healthy elodea under water. These might be cut on the day preceding the experiment. Caution the student not to tie the glass rod too tightly to the sprig of elodea. This may injure the stem. The sodium bicarbonate is added to each tube to provide the carbon dioxide needed. Lack of carbon dioxide in the environment may alter the results of the experiment. The tubes should be left in their respective environmental conditions for fifteen minutes. One student may be assigned to count the bubbles being emitted from the base of the stem while another checks the time. Caution the student to watch for the bubbles that are being emitted from the stem. Elodea does not release oxygen through the leaves.

In the study of the effect of temperature on photosynthesis, one pair of students may be assigned to check one elodea sprig at a given temperature while others are checking the remaining sprigs at other temperatures. This will save time for other activities in the laboratory. Caution the student to leave the sprig of elodea in the tube at various levels until oxygen bubbles are emitted. The temperature of the water in the tube will be the same as that of the water bath in which it is contained.

Interpretation. Oxygen is a by-product of photosynthesis. When the light intensity is reduced or light is not available, the rate of photosynthesis is slowed down or stops. A decrease in temperature slows down the rate. If the temperature is too high, the rate is also slowed down because of chlorophyll destruction.

C Part 5 The Effect of Various Visible Light Wavelengths on the Growth of Green Plants

Suggestions for procedure. This Part should be done as a group project or demonstration. The bean plants should be approximately four inches high with one set of well developed leaves. The cellophane paper should be fastened tightly around the rim of the flower pot. Caution the student to check for any cracks in the paper. No outside light should be available to the plants. Putting the plants in the room with the same lighting conditions excludes light as a variable condition. Caution the student to cover the plants carefully following the watering.

Students will use the starch test for the presence of starch to determine the effect

of various visible light wavelengths on the growth of the bean plants. They should also note the size and color of the leaves and stems. The results should be prepared as a table.

Analysis and conclusions. On the basis of the results of the starch test and the chlorophyll production in the various tissues of the bean plants, the student should draw some valid conclusions relating to the source of energy provided by the various environments. The plant growing under the clear cellophane should give good results, since all the wavelengths of the visible spectrum are available. The plants growing under the blue cellophane have the poorest results and the one growing under red cellophane the best. Blue light waves inhibit the production of starch in land plants.

Chapter 7

Cell Metabolism

The nutritional aspects of the cell have been presented as a background for understanding the activities of the cell. The students should have a clear understanding that the chemical changes occurring in living cells (metabolism) can be divided into two phases. One, anabolism, is the build-up process in which the nutrients are combined to form more protoplasm or products of the cell. Protein synthesis is an important part of the anabolic phase. The other phase, catabolism, involves the breakdown of existing cellular material to release energy for the cell's activity in growth, reproduction, secretion, or repair.

Respiration is a very important activity of protoplasm because it involves the liberation of chemical energy from the organic molecules within living cells. Directly or indirectly the energy content of any organic molecule is stored solar energy. It is important that students understand that most energy results from oxidation of a nutrient involving either the removal of hydrogen or the addition of oxygen. Most of the energy reactions in living things involve the release of hydrogen. An understanding of the basic difference between aerobic and anaerobic respiration is very important. Emphasize that in aerobic respiration, oxygen is the final hydrogen acceptor, with water formed as a by-product. Pyruvic acid is the hydrogen acceptor in anaerobic respiration. Emphasize that pyruvic acid is a normal product of respiration in any cell, but that the presence of oxygen causes it to be oxidized as a fuel, and that only when there is a lack of oxygen does the pyruvic

acid replace oxygen as a hydrogen acceptor.

Protoplasm must produce new protoplasm to balance its continuous destruction through respiration. The authors have included the most recent information on protein synthesis by template and transfer RNA. Protoplasm changes constantly, but continues to maintain the basic properties that give it life. Special emphasis should be placed on metabolism as it relates to the continuity of life. Point out to the students the interrelationship of the main processes and results of metabolism.

Outside activities for this chapter may include reading and reports on any of the phases of cellular metabolism. An interesting and valuable report might include the methods by which scientists learn about the activities of the cell. How do we know about the function of transfer RNA? Is the function of this substance a fact or a theory? The preparation of a bulletin board showing the cellular components and describing their function is a good short-term project.

P. 94, right column: The field of organ transplantation is one that occupies many scientists today. Different methods are being tried to get the body to accept the organ of the donor. Kidney transplants of unrelated individuals have been tried, as have the transplantation of a chimpanzee heart to a human and the transfer of a lung from a recently deceased person to another human. The problem of dissimilarity of proteins in individuals is large and one method of resolving it is to subject the

donated organ to X rays. Interesting student reports could be made on this topic.

P. 99: Compare Figs. 7-3 with 7-4 and discuss the importance to man of the end products of each process.

Suggested Films

Cell Respiration (col, 28 min) AIBS McGraw-Hill

MAJOR CONCEPTS

1. Metabolism involves destructive, or tearing-down, processes as well as constructive, or building, processes.
2. Although protein synthesis occurs in all living matter, a cell builds specific proteins which vary from species to species, individual to individual, and even in various kinds of cells in the same organism.
3. Ribosomes are the centers of protein synthesis. They receive directions from DNA in the nucleus through messenger RNA, which acts as a template on the surface of the ribosomes.
4. The breakdown of molecules and the release of chemical energy in the cell occurs during respiration.
5. Oxidation involves either the addition of oxygen or the removal of hydrogen from a molecule with an accompanying release of energy.
6. Mitochondria are the centers of cellular respiration. They may store energy by adding a high-energy phosphate group to ADP to form ATP.

ANSWERS TO QUESTIONS FOR REVIEW (Page 102)

1. Metabolism is the sum total of the cell's chemical activities. The constructive phase, anabolism, includes the building of protoplasm, protein synthesis, secretion, etc. The destructive phase, catabolism, involves the use of cellular material in respiration to release energy used in maintaining the living condition, growth, repair, and reproduction.
2. Protein synthesis is a universal phase of cellular anabolism. Carbohydrate synthesis is limited to the photosynthetic autotrophs. All cells capable of photosynthesis organize the same PGAL and glucose molecules in the

same series of chemical reactions. This is not true of proteins. A cell builds specific proteins which vary from species to species, individual to individual and, to some extent, in various kinds of cells in the same organism.

3. Structural proteins are found in cytoplasm, membranes, cytoplasmic inclusions, and nucleotides. Enzymes are protein molecules.
4. DNA contains four kinds of bases: adenine, thymine, guanine, and cytosine. RNA molecules contain all these bases except thymine, for which uracil, another base, is substituted.
5. Messenger RNA molecules are formed and stored for a while in the nucleus. They leave the nucleus and move to the ribosomes to deliver their instructions for protein synthesis. They attach to the ribosomal surfaces and form patterns, or templates, for the formation of a specific protein.
6. Transfer RNA delivers amino acids to the ribosome, where they are assembled into proteins.
7. With the exception of uracil, the base sequence in transfer RNA is the same as that in the nucleotides of the DNA in the nucleus. DNA duplicates its code in the strands of transfer RNA by means of messenger RNA.
8. The energy released in a cell during respiration results from the oxidation of glucose. Oxidation involves either addition of oxygen or removal of hydrogen from a molecule, with an accompanying release of energy. Most oxidation in a cell is by the removal of hydrogen.
9. Fuel fragments, hydrogen, and energy.
10. Energy released from the oxidation of glucose is used in adding a phosphate group to a molecule of ADP. The resulting ATP, a higher energy compound, then may move to any part of the cell and supply energy as it is needed. The removal of one phosphate group from ATP releases energy and reforms ADP.

ANSWERS TO APPLYING PRINCIPLES AND CONCEPTS (Page 102)

1. In the first step of protein synthesis, a DNA molecule synthesizes a single-stranded molecule of RNA similar in form and coded in the exact manner as the DNA molecule. This template RNA moves to the ribosome where it is laid down as a chemical mold. Meanwhile, transfer RNA brings specific amino acids to the ribosome where they are joined together according to the mold.
2. Proteins are specific in living organisms because of the enormous variety of proteins possible. Various proteins are composed of different numbers and arrangements of approximately 20 amino acids. The amino acids are linked together in a linear chain. Other groups of atoms are attached to the amino acid chains to form molecules of amazing complexity. The size and complexity of protein molecules is indicated in their formulas, in which the number of atoms may range from a few thousand to several million in the extremely complex and largest of all molecules. The DNA in every cell controls the protein that will be formed.
3. A code consisting of a single base would encode four amino acids, since there are four different bases. A code consisting of two bases would encode 4^2 , or 16, amino acids. As it is, the code consisting of three bases could encode 4^3 , or 64, amino acids, if there were that many.
4. An energy transport system such as that of the ATP molecule is vital to a cell because energy must be drawn at any time and area of the cell.

Guide to Laboratory Investigations for Chapter 7

INVESTIGATION 7-1

Cellular Respiration

Scope of the Investigation In the study of respiration in elodea and germinating seeds, the student observes that carbon dioxide is a fuel fragment of oxidation as discussed on p. 99 of the text. This Investigation emphasizes that respiration is an activity of living cells all the time, both in light and darkness. The increase in temperature in the fermenting apple cider is graphic evidence of heat energy production during cellular respiration (p. 100 of the text).

Approximate time required The preparation of sufficient brom thymol blue indicator solution for Parts 1 and 3 will require about 15 minutes. It will require about 10 minutes to set up the culture tubes for the elodea demonstration. However, it will require about six to eight hours for the student to observe a change from blue to yellow in the brom thymol blue. Periodic inspections of the tubes should be made by a student as his class schedule permits or by the teacher.

The seeds used in Part 2 may be soaking during the preparation of Part 1. One set of seeds will require 20 minutes to soak; the second set will require an hour. The seeds can continue to soak during the preparation of the setup in Part 3. These will have to be held until the next class period since one set of seeds is soaked overnight. A student or the teacher will have to watch the setup carefully to note the color change from blue to yellow in the setup containing the disinfected seeds. The student will need 15 minutes to prepare the setup in Fig. 7-1-a.

The setup in Fig. 7-1-b can be prepared in 30 minutes. However the experiment should run for seventy-two hours. Other laboratory activities should be done while the experiment is running.

A Part 1 Production of Carbon Dioxide by Elodea

Suggestions for procedure. The solution of brom thymol blue should be prepared in sufficient quantity for use in Parts 2 and 3 as well as this Part. Dissolve 10 gm of brom thymol blue in 1,000 ml of water. Then have the student add one drop (0.1 ml) of ammonium hydroxide from a dropping pipette to the brom. thymol solution. Since elodea sprigs will be put in four of the test tubes, the student must not fill them too full of the brom thymol blue solution. The sprigs of elodea should be young and growing vigorously. The tubes should all be checked periodically to note when a color change occurs. The tubes containing elodea that are placed in the dark will show a color change from blue to yellow.

Student observations—answers to questions.

- (a) The two tubes containing brom thymol blue and elodea in the dark.
- (b) Carbon dioxide was produced during respiration, resulting in a change from an alkaline to an acid environment.
- (c) Six to eight hours.

A Part 2 Respiration in Germinating Seeds

Suggestions for procedure. The seeds may be soaked in the 5% formalin solution to disinfect them during the period that other Parts of the Investigation are being done. Caution the student to wash these seeds with cold water and soak them overnight. Point out that soaking the seeds in a 10% formalin solution for an hour will kill the cells in the seeds. Be sure that the student identifies the two sets of seeds. Demonstrate the method of inserting glass in the one-hole stoppers. The setup should be left for two or three days until a color change has been noted in the gas bottle containing the living seeds. Emphasize that the color change does not occur in the setup containing the killed seeds because only living cells carry on respiration. Point out that a control is necessary for all experiments.

Student observations—answers to questions.

- (a) The brom thymol blue in the setup with the living seeds turned yellow.
- (b) Carbon dioxide given off during respiration of the living cells changed the alkaline environment of the brom thymol blue solution to acid. There was no color change in the setup with the killed seeds.

B Part 3 Energy Release During Respiration

Suggestions for procedure. This Part is best suited to a demonstration by a student or group of students. The apparatus for the demonstration of energy release should be left at room temperature. Be sure to use fresh apple cider that has not been pasteurized or had a preservative added. Juice that has been squeezed from fresh, unwashed purple grapes may be substituted for the apple cider. Molds may contaminate the cider, but they do not interfere with the results to any great extent. Be sure that the thermometer extends into the apple cider so that the heat energy can be measured. The rise in the temperature over the seventy-two hour period is visible evidence that heat energy is being produced.

If limewater is used in the gas bottle, the carbon dioxide produced during fermentation will turn it milky. The brom thymol blue will change from blue to yellow. Have the students remove the thermometer and smell the fermented juice to determine that alcohol is also produced. The observation that carbon dioxide and alcohol are produced in the fermentation process should lead the students into a discussion of anaerobic respiration.

Student observations—answers to questions.

- (a) One.
- (b) The yeast cells, which are responsible for the fermentation, are present in one Thermos only.
- (c) There was no change in the brom thymol blue in the gas bottle of the control; the brom thymol blue in the gas bottle of the experimental changed from blue to yellow.
- (d) The carbon dioxide produced during fermentation in the Thermos of the experimental caused the color change.
- (e) Alcohol.
- (f) Smell the contents of the Thermos bottles.
- (g) Anaerobic.
- (h) Carbon dioxide and alcohol are products of anaerobic respiration.

Interpretation. Yeast cells were present in the experimental Thermos, resulting in the fermentation of the apple cider. They were not present in the other Thermos.

Yeast cells lack the necessary enzymes for aerobic respiration.

Chapter 8

Cell Growth and Reproduction

This chapter forms a basis for the understanding of reproduction in plants and animals. DNA has already been discussed as bearing a code for protein synthesis. This chapter tells how DNA functions in carrying the genetic code of the cell. The DNA molecules, or genes, in the chromosomes are emphasized as the physical bearers of heredity and the regulators of cell processes. The teacher should emphasize that DNA controls the entire nature of a cell and that each cell contains the same kind of genes. The influence of the gene on a given cell is regulated by the chemical differences in the cytoplasm of cells.

The necessity of mitosis becomes apparent as a means of producing daughter nuclei with the same genetic makeup. Meiotic divisions and chance distribution of genes and chromosomes during reduction division account for the variations in the heredity makeup of organisms. It should be stressed that, although meiosis and mitosis are studied in stages, the processes are continuous.

Students can make models, diagrams, and bulletin boards showing the cell and its chromosomal changes during mitosis and meiosis. Special projects might include photographs or drawings from a microscopic study of onion root-tip cells or whitefish eggs.

P. 105, Fig. 8-2: Use this as the basis for a well-planned lesson on mitosis. The students may keep books open and follow the lesson as the teacher used colored chalk for labelled board diagrams. In each diagram use the same color chalk for each structure to help students follow the changes that occur in each of the structures.

P. 105, left column: The centrioles travel to opposite sides of the cell to act as poles.

P. 107, right column: Cell division, stimulated by injury, continues until the wound is healed and then stops. Apparently in tumors this does not occur because cells continue to multiply and invade surrounding tissue.

P. 108, Fig. 8-5: Have on hand examples of vegetative reproduction like a white potato sprouting, a piece of willow with roots, and a piece of pickaback plant (*Tolmiea menziesii*). If these are kept throughout the year they can serve several purposes.

P. 109, Fig. 8-6: Have students bring in bread wrappers or cake wrappers to read the labels and discover the mold inhibitor used commercially. Moldy fruits and bread can be brought in and mounted under the microscope.

P. 111, Fig. 8-7: Go over this diagram carefully. The process of making a mature sperm and egg also involves mitosis as well as meiosis. Compare the number of sperm produced with the number of eggs, especially in humans. Use this diagram to lead into the next unit on heredity.

Suggested Films

Cell Biology: Mitosis and DNA (b&w&col, 16 min) Cor

Cell Reproduction (Mitosis) (col, 28 min) AIBS McGraw-Hill

Growth and Replacement (col, 28 min) AIBS McGraw-Hill

Meiosis: Sex Cell Formation (b&w&col, 16 min) EBF

Mitosis and Meiosis (b&w&col, 17 min) Ind

MAJOR CONCEPTS

1. There is a critical relationship between the volume of cell content and the surface exposure of the plasma membrane.
2. Cell growth is normally followed by cell division.
3. The key components of the nucleus are the molecules of DNA as they bear the genetic code of the cell.
4. Mitosis produces daughter cells which are structurally and functionally like the mother cell.
5. In some instances mitosis constitutes reproduction.
6. Meiosis produces cells that are haploid, containing one chromosome of each homologous pair.
7. In sexual reproduction, fertilization forms the zygote and restores the diploid chromosome number.

ANSWERS TO QUESTIONS FOR REVIEW (Pages 113-114)

1. Binary fission is the division of a cell into two approximately equal parts.
2. a. Duplication of nuclear materials;
b. cleavage of the cytoplasm into two approximately equal parts.
3. DNA molecules bear the genetic code of the cell as determined by

the nature and sequence of base pairs joined in the double helix of the molecule. DNA molecules are joined to protein molecules to form units we refer to as genes. Genes in turn are linked in linear strands, or chromosomes.

4. Following the formation of a daughter cell and prior to a subsequent division, there is a period of growth and enlargement—the interphase. During this time the nucleus, in addition to directing protein synthesis, is preparing for a coming division during at least the latter part of the interphase. DNA molecules are doubling their structure and reproducing genes and chromosomes.
5. In animal cells the earliest event in cell division that is noticeable is the division of the centriole, a cytoplasmic body lying just outside the nucleus.
6. When the centriole has divided, the pairs move apart and finally occupy positions on opposite sides of the nucleus. The cytoplasm around each centriole changes in form from sol to gel and forms fibrils which radiate from the centriole like rays from a star. These are called asters.
7. The spindle is composed of additional fibrils between the centrioles. It is along the spindle that the chromosomes appear to be pulled apart as they are duplicated, so that one of each pair enters the daughter cell.
8. The chromosome is a rod-shaped, gene-bearing body formed in the cell nucleus during division. The chromatid is one of the parts of a double chromosome.
9. During prophase the centriole appears, divides, and separates. The asters and spindles form, and the chromosomes duplicate.
10. The chromatids are attached to the spindle fibers at the point of the centromeres.
11. Chromosome migration occurs from the equator to the poles. Each chromosome moves along a spindle fiber and is pulled toward the pole.
12. This phase includes the reorganization of daughter nuclei and the divi-

sion of the cytoplasm to form two daughter cells. After the chromosomes reach their respective poles, they lengthen and gradually disappear, leaving only a granular substance in the nucleus. The spindle fibers and asters of animal cells disappear as their substance reverts from gel to sol. New nucleoli are organized and a new membrane forms around each nucleus.

13. In plant cells neither centrioles nor asters form. Instead a spindle of protein fibers extends from one end of the cell to the other. In plant cells cellulose molecules form a wall across the cell in the region of the equator. This primary wall, or division plate, forms a common boundary between the daughter cells.
14. In unicellular organisms binary fission consists of reproduction. Yeast cells, molds, sponges, and some coelenterates may reproduce by budding, which is a growing outward of a part that becomes another complete organism. Many plants may be started by breaking off a piece and keeping it in moist sand or soil. Potatoes, roses, and geraniums are examples of this vegetative reproduction. Many organisms form spores, which are reproductive cells formed by divisions of special cells.
15. A gamete is a sex cell. Two gametes unite in fertilization and form a zygote, which then develops into a complete organism. A spore is an asexual reproductive cell. Spores are usually protected by a resistant wall and may endure severe environmental conditions such as drying or freezing. The spore does not fuse with another spore in the production of a new organism.
16. Isogametes are sex cells which are identical in size, shape, and appearance. Heterogametes are different in size and shape, the male gametes being sperm, the female gametes being ova or eggs.
17. They are identical in form, gene composition, and linear arrangement of genes.
18. When a cell contains a full set of

homologous pairs of chromosomes, we say that it has the diploid, or $2n$, chromosome number. Gametes, however, contain one chromosome of a homologous pair. Thus it is said to have the haploid, or n , number.

19. Mitosis is a duplication division in which each daughter cell is identical and both are diploid. Meiosis is a reduction division in which the chromosome number is reduced to the haploid condition in the daughter cells. The resulting cell is a gamete.
20. In meiosis, the homologues of each chromosome pair join throughout their lengths at the equatorial plate. While the chromosome pairs are in synapsis, they shorten and thicken and coil about each other. Meanwhile, replication is occurring and chromatids appear, each "twin" joined by a centromere. This results in a tetrad, or group of four chromatids. The chromosome number is now tetraploid ($4n$), since each chromatid contains a full set of genes.
21. The primary oocyte divides following migration of the paired chromatids, forming a secondary oocyte and the first polar body. The secondary oocyte soon divides again, forming an ootid and a second polar body. Both the ootid and the second polar body now contain the haploid (n) chromosome number. A similar division also occurs in the first polar body. The joined chromatids separate and two additional second polar bodies, each with the haploid (n) chromosome number, are formed. The ootid matures into an egg and the three polar bodies have no function in reproduction and gradually disappear.
22. In the case of sperm production, however, the primary spermatocyte divides and forms two functioning secondary spermatocytes. These in turn form four spermatids, each of which matures into a functioning sperm.
- During fertilization the $2n$ chromosome number is established. This also creates the zygote, which grows into a complete organism.

ANSWERS TO APPLYING PRINCIPLES AND CONCEPTS (Page 114)

1. As a cell increases in size one of two things must happen. Either its rate of synthesis must slow down or it must divide its mass. Otherwise its increase in mass would bring about its death. Nutrients must pass into the cell through the plasma membrane and wastes must pass out of the cell through the same membrane. Thus, a critical relationship exists between the volume of a cell and the surface exposure of the membrane. As a cell grows, the area of the surface does not increase proportionally with the volume.

The exact mechanism for triggering cell division, however, is not known. Some recent theories are: change in ratio of the cytoplasm to the nucleus; change in the surface to volume ratio; increase in the DNA content of the cell; role of the nucleolus; role of chromosomes; increase in a coagulation substance.

2. Cell division results in reproduction on a cellular level. It may result in reproduction of an organism, as in many protists, or an increase in the mass of a tissue, as in the growth of a multicellular organism.

Meiotic cell division, however, results in the formation of a haploid cell, or gamete, which fuses with another gamete during the process of fertilization. The resulting zygote then grows by successive cell divisions resulting in another multicellular organism resembling the parents. In the unicellular organisms, however, the zygote requires less differentiation to form the organism.

3. Mitosis, or multiplication division, results in the formation of daughter cells which are genetically like the mother cell. In unicellular organisms this is one form of reproduction. In others, mitosis may form resting cells or spores which grow into a complete organism at a later time. In other multicellular organisms, mitosis results in growth by adding to the number of cells, and therefore in mass of the tissues.
4. In asexual reproduction there is an exact duplication of genetic material so that the offspring does not differ from the parent. Therefore, the parental characteristics are perpetuated.
5. Sexual reproduction allows a combination of characteristics of two parents. Therefore, the offspring are not exactly like either parent.

Guide to Laboratory Investigations for Chapter 8

INVESTIGATION 8-1

Cell Growth and Reproduction

Scope of the Investigation As the student studies the prepared slides showing mitotic stages, he should gain a graphic understanding of the principle of mitosis as discussed on pp. 104-107 of the text. A grasp of what happens to chromosomes when a cell divides is important to an understanding of genetics, which the student will study in Unit 2. The study of plant and animal tissue should make the student aware that the principle of mitosis is the same in plant and animal cells; only the details differ.

The preparation of the smear of the onion root tip will enable the student to become familiar with some microtechnique and staining, and help him to understand that the materials on the prepared slides came from living tissue. However, much of the nuclear material is destroyed in sectioning for preparations. The smear technique is superior to the sectioning one because the student should be able to see complete cells and nuclei in division.

As the student performs each step in the study of meiosis, which he studied on pp.

109-112 in the text, he should note some similarities to the process of mitosis, but the differences are very important. From his work with the diagram, he should gain a concept of reduction division and an understanding of the necessity for the formation of gametes with a haploid number of chromosomes.

As the student works with the diagram showing chromosome changes during fertilization and division of the zygote, he will demonstrate the restoration of the diploid number of chromosomes (p. 112 of the text).

Approximate time required The student should be able to complete Parts 1 and 2 in 50-60 minutes. Part 3 can be completed in 50-60 minutes if all the materials have been assembled previously. The onion root tips will require about five days growing period.

A Part 1 Study of Mitosis Using Prepared Slides

Suggestions for procedure. In teaching the concept of mitosis, stress the basic concept of replication of chromosomes. Point out that the various stages that occur following replication and that precede division of the cell into two daughter cells can be distinguished by the density of the chromosomes, the presence or absence of the nucleolus, by the development of the spindle, by chromosome attachment by centromeres, by the migration of the chromosomes along the spindle fibers to the poles, and by the reorganization of the nucleus. Emphasize the relationship of the new daughter cells to the parent cell and cellular continuity that results from mitosis. Point out that mitosis insures genetic continuity and identity of the daughter cells.

The location of the various stages of mitosis and the drawings should be done carefully so that the student gains a graphic understanding of the mitotic divisions. In the study of mitosis in the plant and animal cell, point out that the principle is the same. There are however, slight differences in detail which the student should find as he examines the two prepared slides that are suggested.

Student observations—answers to questions.

- (a) The chromosomes migrate along them to the poles.
- (b) Across the center of the equatorial plate.
- (c) Separate the two daughter cells.
- (d) A centriole is present at the poles of the spindle of the animal cell.
- (e) Animal cells pinch in two; plant cells form a cell wall between the daughter cells.
- (f) Centrioles.
- (g) Chromosomes and spindle fibers.

A Part 2 Meiosis and Fertilization

Suggestions for procedure. Point out that the diagram provided is being used to emphasize that the chromosomes are reduced to half their original number when the gametes are formed. Chromosomes are passed on from parent to offspring and each parent provides one half of the chromosomes present in the offspring and one of each homologous pair. Therefore, during fertilization the chromosome number is restored. The zygote that is formed has a $2n$ number of chromosomes and it will divide, forming two daughter cells with the $2n$ number of chromosomes by the process of mitosis.

B Part 3 Preparing Smears of Onion Root-Tips

Suggestions for procedure. The onion root tips will require about five days for growth. The setup in Fig. 8-1-c will have to be prepared well in advance of the preparation of the root-tip smears.

The acetocarmine stain should be prepared and ready for use when the root tips are prepared. To prepare the stain, boil a 45% acetic acid solution in a beaker and add carmine powder until the solution is saturated. Store the solution in 2-oz dropping bot-

ties for use. Caution the student to use care in cutting off the lower, denser half of the onion root tip into the watch glass. The flame should be turned low enough so that the acetocarmine solution does not boil. The student should put the piece of onion root tip on a slide, add fresh stain, and locate an area of the root tip that has the deepest stain. Point out that this portion is better to use since the nuclear materials will stain with the acetocarmine. Emphasize the necessity for macerating the root tip and that they must press firmly and steadily on the cover glass so as to flatten and separate the cells into a thin layer. They should examine the entire slide under low power of the microscope before examining the mitotic figures under high power. Point out that the chromosomes they are observing came from cells that were undergoing mitosis at the time they were killed, and that nuclei that are not undergoing mitosis do not show these structures.

Student observations—answers to questions.

- (a) Probably not.
- (b) Parts of the chromosomes are often cut away during sectioning.

Interpretation. Only growing tissues have actively dividing cells.

Suggested References for the Teacher—Unit I

Books

Asimov, Isaac. *Building Blocks of the Universe*. Abelard-Schuman, Ltd., New York, 1957

Asimov, Isaac. *The Chemicals of Life*. Abelard-Schuman, Ltd., New York, 1954

Beeler, Nelson F. and Branley, Franklyn M. *Experiments with a Microscope*. Thomas Y. Crowell Co., New York, 1957

Chambers, R. and Chambers, E. L. *Explorations into the Nature of the Living Cell*. Harvard University Press, Cambridge, Mass., 1961

Conn, E. E., and Stumpf, P. K. *Outlines of Biochemistry*. John Wiley and Sons, New York, 1963

Cook, James Gardon. *We Live by the Sun*. The Dial Press, New York, 1957

Cooper, Elizabeth K. *Science in Your Own Backyard*. Harcourt, Brace and World, New York, 1958

Cope, Zachary. *Florence Nightingale and the Doctors*. J. B. Lippincott Co., Philadelphia, 1958

Corrington, Julian. *Exploring with Your Microscope*. McGraw-Hill Book Co., New York, 1958

Dobell, Clifford. *Anton Van Leeuwenhoek and His Little Animals*. Russell and Russell, New York, 1958

Dubos, R. J. *Louis Pasteur, Free Lance of Science*. Little, Brown and Co., Boston, 1950

Gabriel, M. L. and Fogel, S. (eds.). *Great Experiments in Biology*. Prentice-Hall, Englewood Cliffs, N.J., 1955

Giese, A. C. *Cell Physiology*. 2nd ed. W. B. Saunders Co., Philadelphia, 1962

Hardin, Garrett. *Biology: Its Human Implications*. W. H. Freeman and Co., San Francisco, 1952

Harrison, K. *A Guide-book to Biochemistry*. Cambridge University Press, London, 1959

Hulton, R. G. *Handbook of Plant and Floral Ornament from Early Herbals*. Dover Publications, New York, 1960

Jean, F. C. *Man and His Biologic World*. Ginn and Co., Boston, 1958

Mavor, J. W. *General Biology*. 5th ed. The Macmillan Co., New York, 1959

McElroy, W. D. *Cellular Physiology and Biochemistry*. Prentice-Hall, Englewood Cliffs, N.J.

Mercer, E. H. *Cells: Their Structure and Function*. Doubleday & Co., New York, 1962

Meyer, Jerome S. *The Elements: Builders of the Universe*. World Publishing Co., Cleveland, 1957

Milne, Lorus and Milne, Margery. *The Biotic World and Man*. Prentice-Hall, Englewood Cliffs, N.J., 1958

Moulton, F. *The Cell and Protoplasm*. The Science Press, Lancaster, Pa., 1940

Porter, K. R., and Bonneville, M. A. *An Introduction to the Fine Structure of Cells and Tissues*. Lea & Febiger, Philadelphia, 1963

Roberts, E. D., Nowinski, W. and Saez, F. A. *General Cytology*. 3rd ed. W. B. Saunders Co., Philadelphia, 1960

Schrader, F. *Mitosis*, 2nd ed. Columbia University Press, New York, 1953

Scientific American. *The Physics and Chemistry of Life*. Simon and Schuster, New York, 1956

Sears, P. B. *Where There Is Life*. Dell Publishing Co., New York, 1962

Shippen, Katherine B. *Men, Microscopes, and Living Things*. The Viking Press, New York, 1955

Simpson, G. G., Pittendrigh, C. S. and Tiffany, L. H. *Life: An Introduction to Biology*. Harcourt, Brace and World, New York, 1957

Singer, Charles. *A History of Biology*. Rev. ed. Abelard-Schuman, Ltd., New York, 1958

Stevens, Russell B. *Career Opportunities in Biology*. Row Peterson and Co., Evanston, Ill., 1956

Storer, T. I., and Usinger, R. L. *Elements of Zoology*. 2nd ed. McGraw-Hill Book Co., New York, 1961

Swanson, C. P. *The Cell*. Prentice-Hall, Englewood Cliffs, N.J., 1960

Villee, C. A. *Biology*. 5th ed. W. B. Saunders Co., Philadelphia, 1964

White, P. R. *The Cultivation of Animal and Plant Cells*. 2nd ed. The Ronald Press Co., New York, 1963

White, T. H. *The Bestiary*. G. P. Putnam's Sons, New York, 1954

Winchester, A. M. *Biology and Its Relations to Mankind*. D. Van Nostrand Co., Princeton, N.J., 1958

Articles

Arnold, J. R. and Martell, E. A. "The Circulation of Radioactive Isotopes." *Scientific American*, September, 1959

Arnon, Daniel I., "The Role of Light in Photosynthesis." *Scientific American*, November, 1960

Brachet, Jean, "The Living Cell." *Scientific American*, September, 1961

Duveen, D. I. "Lavoisier," *Scientific American*, May, 1956

Green, David, E., "The Mitochondrion." *Scientific American*, December, 1964

Holtzer, Heinz, "How Things Get Into Cells." *Scientific American*, September, 1961

Huang, Su-Shu, "Life Outside the Solar System." *Scientific American*, April, 1960

Lehniger, A., "Energy Transformation in the Cell." *Scientific American*, May, 1960

Lehniger, A., "How Cells Transform Energy." *Scientific American*, September, 1961

Mazia, D., "Cell Division." *Scientific American*, August, 1953

Mazia, D., "How Cells Divide." *Scientific American*, September, 1961

Muller, Erwin, W., "Atoms Visualized." *Scientific American*, June, 1957

Neurath, Hans, "Protein-Digesting Enzymes." *Scientific American*, December, 1964

Perutz, M. F., "The Hemoglobin Molecule." *Scientific American*, November, 1964

Robertson, J. D., "The Membrane of the Living Cell." *Scientific American*, April, 1961

Sager, Ruth, "Genes Outside the Chromosomes." *Scientific American*, January, 1965

Solomon, Arthur K., "Pores in the Cell Membrane." *Scientific American*, December, 1960

Spiegelman, S., "Hybrid Nucleic Acids." *Scientific American*, May, 1964

Stein, W. H. and Moore, S. "Chemical Structure of Proteins." *Scientific American*, February, 1961

Wilson, M., "Priestley." *Scientific American*, October, 1954

UNIT TWO

THE CONTINUITY OF LIFE

The sequence chosen for topics in a biology course depends on many factors. In view of the thorough and modern treatment of the cell and its organelles in Unit One, it seems logical that genetics should follow. Having discussed chromosomes, DNA and its replication, and cell division, the process of cellular and organismic reproduction becomes much more meaningful to the student. This unit progresses from the principles of heredity to a discussion of the genetic material by which characteristics are passed on to offspring. The next chapter develops an understanding of the use of a knowledge of gene frequency in populations. Since students are always interested in themselves, the human is used as a familiar example.

In introducing the study of heredity, we suggest a discussion of heredity and environment as influences, especially in human inheritance. Students can refer to certain of their own characteristics that they believe they have inherited. In such a discussion, point out species characteristics, which make all people similar, and individual characteristics, which make them different. The discussion can lead to some of the false ideas about heredity, such as the supposed influence of blood. Then point out that hereditary traits are carried in every cell of an organism.

The practical use of a knowledge of heredity is shown in a discussion of plant and animal breeding. Organic variation and various theories of evolution are presented in the following chapter. The closing chapter of Unit Two deals with the diversity of life and man's artificial systems of grouping and naming various organisms.

OUTCOMES

The study of this unit should result in:

1. Awareness of the part heredity plays in determining the characteristics of organisms.
2. Understanding of the characteristics transmitted from parents to offspring.
3. Familiarity with Mendel's laws of heredity and the significance of his contribution to modern genetics.
4. Knowledge of laws and principles of heredity which have been discovered since Mendel's work.
5. Application of the laws and principles of heredity in an explanation of many phases of human inheritance.
6. An understanding of how our knowledge of heredity has been increased by scientists using many different organisms and many methods.
7. Acquaintance with methods used in controlling inheritance in plant and animal breeding and in taking advantage of natural variations in the practice of mass selection.
8. Familiarity with hybrid plants and animals and new strains, breeds, and varieties of organisms which have been produced by hybridization.
9. Awareness that living things have changed through the ages and that further changes will occur in ages to come.
10. Understanding of various reasons for these changes and of various theories which have been advanced by biologists of past years.

Chapter 9

Principles of Heredity

Mendel's laws introduce the principles of heredity in this chapter. In teaching these laws, we suggest that you emphasize the behavior of the genes involved during reduction, and recombination during fertilization. An understanding of gametogenesis avoids a purely mechanical approach to the diagramming of possible gene combinations in Punnett squares. The law of independent assortment becomes apparent when more than one pair of genes is involved in a cross.

The 1:2:1 ratio of possibilities, occurring in a monohybrid with incomplete dominance and in the phenotype ratio of a monohybrid with dominance, can be illustrated by flipping two coins 50 times or more. Keep a record of the number of times the coins fall with two heads, one head and one tail, and two tails.

The idea of probability and its significance in the genetic transmission of traits should be understood by all the students. A die can be used effectively to show that the chances of rolling a specific number would be one out of six. But what are the chances of rolling the same number again? Although student answers will vary, they can soon see that the chances are again one out of six. Now, what are the chances of rolling two of the same numbers in succession? The law of probability states that, "the chances of two independent events occurring simultaneously is the product of the chances of their occurrence separately." Therefore, the chances would be $1/6 \times 1/6$, or $1/36$.

From this understanding, it is easy to diagram the chromosomal segregation and recombination of a specific characteristic. A treatment of the X and Y chromosomes in producing the 1:1 ratio of either male or female offspring provides a good elementary example. You may show that a couple's chances of having a male child is $1/2$. Their chances of having two boys in a row would be $1/2 \times 1/2$, or $1/4$. However, what would be their chances of having the first two children of the same sex? The

wrong answers will help you to explain why the right answer is $1/2$.

When your students have these concepts in mind, they are well on their way to understanding the principles of heredity and will avoid the necessity of memorizing presented facts.

P. 116: When students discuss the influence of environment, it is important that they understand that unless an individual tries an activity or skill, such as music, linguistics, or athletics, he will not find out if he has ability along that line. Students do not become good athletes unless they have the physical requirements and develop them by practice.

P. 120, right column: During a discussion of Mendel's laws, common superstitions such as "traits skip a generation" and "actions of a mother before birth determine certain traits of the offspring" can be discussed.

P. 122: It is important to explain to students that in Punnett squares the letters representing traits are paired at the top and sides of the grid because the genes in the gametes are paired. In the diagram at the top of page 122, have the students express the phenotypes and the genotypes of all these plants (they are tall because tallness is dominant). They have a hidden recessive for shortness. Review here Mendel's laws governing unit characters. (p. 119) and dominance (p. 120).

P. 123: Have students state from the diagrams the results of crossing a pure dominant with a hybrid and a pure recessive with a hybrid.

P. 125: Crossing dihybrids is easier to understand if students list all the possible combinations of the genes first as RY , Ry , rY , ry . Fig. 9-6 is useful for expressing how each offspring looks and what its genetic makeup is.

P. 127, bottom right: Have students diagram the cross of the heterozygous black, rough-coated guinea pigs. Stress the fact that large numbers of offspring are necessary to show the ratio.

Suggested Films

Heredity and Environment (b&w&col, 11 min) Cor

Mendel's Experiments (b&w, 30 min) Ind.

Mendel's Segregation (col, 28 min) AIBS McGraw-Hill

The Science of Genetics (col, 28 min) AIBS McGraw-Hill

MAJOR CONCEPTS

1. Heredity and environment both influence an organism's makeup.
2. The transmission of characteristics from parents to offspring is chemically controlled.
3. The chemicals controlling both species and individual characteristics are located in the genes of which the chromosomes are composed.
4. The laws of heredity formulated by Mendel stand today, practically unchanged, as the basis of the science of genetics.
5. Various hereditary characteristics are controlled by factors (genes) which occur in pairs.
6. One factor (gene) in a pair may mask or prevent expression of the other.
7. A pair of factors (genes) is separated during the formation of gametes (spores in some plants) in reduction division.
8. The separation of gene pairs on a given pair of chromosomes and distribution of the genes to gametes (spores in some plants) during reduction division is entirely independent of the distribution of other gene pairs on other pairs of chromosomes.
9. Incomplete dominance occurs when there is an equal appearance of two unlike characteristics in the offspring, resulting from a cross of these characteristics. Thus, a cross between red and white flowering four-o'clocks produces plants that bear pink flowers.
10. Although it is entirely a matter of chance as to which gametes will unite, predictions in breeding experiments may be made. These predictions are based on averages and the expected ratios are accurate only when large numbers of individuals are considered.

ANSWERS TO QUESTIONS FOR REVIEW (Page 129)

1. Hereditary characteristics are carried in genes on chromosomes of the cells. They are fixed characteristics and do not change under ordinary conditions. Furthermore, they are passed on to offspring. Environmental characteristics are external influences on the organism. They are not passed on to offspring.
2. Mendel noticed that garden peas differed in certain definite characteristics. The plants normally carried on self-pollination, but cross-pollination could be performed easily by transferring pollen from the stamens of one flower to the pistil of another.
3. a. Mendel found the following pairs of contrasting traits in garden peas: round seeds, wrinkled seeds; yellow seeds, green seeds; white seed coat, colored seed coat; inflated pod, constricted pod; green pod, yellow pod; axial flowers, terminal flowers; tall stem, short stem; b. round seeds, yellow seeds, colored seed coats, inflated pod, green pod, axial flowers, and tall stem are dominant.
4. In any experiment there should be only one variable if valid conclusions are to be drawn. Mendel limited his study of each cross to a single characteristic involving only one trait at a time.
5. A homozygous black guinea pig has two genes for black. A heterozygous black guinea pig has one black gene and one white gene.
6. The law of segregation is illustrated in the appearance of recessive characters when two hybrids are crossed. Two recessive genes appear in a pair to produce the recessive character.
7. When two parents that are hybrid for one character are crossed, the offspring will show the dominant and recessive characters in a ratio of 3 to 1, respectively.
8. According to the law of independent assortment, the separation of pairs of genes and their distribution to gametes (spores in plants) during reduction division is entirely inde-

pendent of the distribution of other genes.

9. In incomplete dominance, a pair of unlike genes exerts equal influence on the trait it determines.
10. Ratios are averages because many eggs and sperm are involved in the combinations. An exact ratio in a monohybrid would appear only if two eggs and one sperm were produced.

ANSWERS TO APPLYING PRINCIPLES AND CONCEPTS (Pages 129-130)

1. If a black guinea pig is crossed with a white one (pure recessive) and all of the offspring are black (hybrid), the black parent was pure. If both black and white appear, the black parent was hybrid. This is known as a back cross.
2. The phenotypes of the F_1 and F_2 generations can be any possible combination of the three traits (texture, color, hair length) you can name. The chances of the cross producing a recessive for each trait, however, is very slight.
3. In the first cross, all the offspring will be pink-flowering plants with inter-

mediate length leaves. The cross of this F_1 generation is a typical dihybrid cross in which the phenotypic ratio is: 1 red-flowering plant with broad leaves to every 2 pink-flowering plants with broad leaves to every 1 white-flowering plant with broad leaves to every 2 red-flowering plant with intermediate leaves to every 4 pink-flowering plant with intermediate leaves to every 2 white-flowering plant with intermediate leaves to every 1 red-flowering plant with narrow leaves to every 2 pink-flowering plant with narrow leaves to every 1 white-flowering plant with narrow leaves. The 9:3:3:1 ratio is not apparent in the phenotype because of incomplete dominance.

4. A hybridizer has a much better chance of producing a dominant trait in offspring than a recessive one. Furthermore, by knowing which traits in a plant or animal are dominant and which ones are recessive, he can plan crosses to produce the desired trait.
5. The law of independent assortment holds true only when pairs of genes are situated on different chromosomes. The chromosome pairs and not the individual genes are distributed during reduction division.

Guide to Laboratory Investigations for Chapter 9

INVESTIGATION 9-1

Genetic Facts and Fallacies

Scope of the Investigation There are many commonly believed fallacies concerning inheritance. This Investigation is designed to determine the extent to which some persons believe certain statements about heredity. Through a survey technique, the student determines how frequently certain genetic facts are misunderstood and certain fallacies are believed. Many of these statements are related to the material studied in the text on pp. 116-169.

Approximate time required The survey section of the Investigation is done outside of class. The student works in and around his home overnight or over a weekend, to contact 10 or more people. The tabulations and graph construction should require approximately 30-40 minutes in class.

A Part 1 Conducting the Survey

Suggestions for procedure. Each student should be provided with a set of the statements and a means for recording responses. He should select 10 persons of various ages, ranging from his own age (no younger) to the age of his grandparents. It is wise to interview several persons outside the family. The student should be careful not to reveal the answers in any way when reading the statements, nor should he let any of his subjects see the responses of others. The student should tabulate his own results, and add them to the class totals to fill in the table provided and make the graph. In discussing the results of this survey, the teacher should be especially careful not to unintentionally degrade the people who believed the fallacies and not the facts. This survey should reveal that much education is needed in the field of genetics, but should not be considered as any personal reflection on the people (friends and family of the students) who answered the questions of the survey.

INVESTIGATION 9-2

Study of Mendelian Laws

Scope of the Investigation This Investigation is designed to enable the student to determine the results of certain genetic crosses through an understanding of Mendel's laws, which he studied on pp. 116-128 of the text. The B-level Part 3 requires the student to determine the parents of a hybrid by application of Mendel's laws. If a student pursues the C-level Part 4, he will be using living pea plants to demonstrate Mendel's laws and determine the inheritance of size in peas.

Approximate time required Students should be able to complete Parts 1 and 2 within 30-40 minutes.

Part 3 may require a period of 50-60 minutes.

Part 4 is a long-range project requiring approximately three months.

A Part 1 Monohybrid Cross

Suggestions for procedure. It is essential that the student have studied Chapter 9 thoroughly before undertaking any part of this Investigation. Students should carefully read the facts concerning each cross, and then proceed to answer the questions and diagram the crosses.

Student observations—answers to questions.

- (a) Smooth (S).
- (b) Wrinkled (s).
- (c) Heterozygous smooth (Ss).
- (d) Smooth.
- (e) Each parent contributed one gene of the pair.
- (f) The S gene exerted its influence in spite of the presence of gene s . Gene s was prevented from exerting its influence.
- (g) They possess genes for two different traits.
- (h) 3 smooth to 1 wrinkled.
- (i) Homozygous (SS) and heterozygous (Ss).
- (j) Unit characters, dominance, and segregation.

A Part 2 Dihybrid Cross

Suggestions for procedure. Follow the same procedure used in Part 1.

Student observations—answers to questions.

- (a) Black (B) and rough (R).
- (b) White (b) and smooth (r).
- (c) $BbRr$.
- (d) Black and rough.
- (e) The genes for color were distributed independently of the genes for texture.
- (f) No. It is the chromosomes and not the individual genes that segregate during meiosis.

B Part 3 A Study of Inherited Traits in Corn Seed

Suggestions for procedure. Students should be provided with genetic corn showing purple-yellow ratios of 1:1 and 3:1, and corn showing a 9:3:3:1 ratio of purple-smooth-yellow-shrunken seeds. Straight pins are also required for marking the point where counting began. Students should be strongly cautioned against dropping the ears or removing any kernels from the ears. They should count the kernels of each color in each row, and tabulate their results. They should answer the questions and determine the probable parent strains of their specimens.

Student observations—answers to questions. (Section 1)

- (a) Answers will vary. Approximately 50% or 75%; depends on strain.
- (b) Answers will vary. Approximately 50% or 25%; depends on strain.
- (c) 1:1 or 3:1, depending on strain used.
- (d) No.
- (e) A gene for purple would produce a completely purple seed, since purple is dominant over nonpurple.
- (f) They appear in different genetic ratios, indicating that their parents differed genetically.
- (g) Unit characters, dominance, segregation.

Interpretation. Corn having a 1:1 ratio of purple to nonpurple seeds would be the result of a cross between a purple hybrid (Pp) and a nonpurple parent (pp). Corn having a 3:1 ratio of purple to nonpurple seeds would be the result of a cross between two purple hybrids ($Pp \times Pp$).

Student observations—answers to questions. (Section 2)

- (h) Four.
- (i) Purple-smooth, purple-wrinkled, nonpurple-smooth, nonpurple-wrinkled.
- (j) Purple-smooth.
- (k) Nonpurple-wrinkled.
- (l) Probably.
- (m) $PpSs \times PpSs$.
- (n) $PPSS \times ppss$ or $PPss \times ppSS$.
- (o) Segregation and independent assortment.

Interpretation. By analyzing the frequency of appearance of genetic traits of offspring, it is possible to determine the probable genetic makeup of the parents.

C Part 4 A Study of Inheritance of Size in Peas

Suggestions for procedure. The student should be provided with twenty-four little Marvel or Progress #9 strain seeds for dwarf plants and twenty-four Alderman variety seeds for tall plants. The seeds should be planted and cared for according to the instructions in the student manual. The growth of molds and other parasites can be retarded if the soil is sterilized prior to preparing the germination flats. This can be

done by heating the soil in a very hot oven for at least one hour. Sprouting can be speeded up a few days if desired by letting the seeds soak in water 24 hours prior to planting. Longer soaking leads to fermentation. The plants should be watered as needed, with care taken to avoid soaking the soil. To have the flowers of both strains ready for cross-pollination at the same time, the tall peas should be planted about two weeks before the dwarf peas, or the tall plants can be artificially illuminated for 16 hours a day to speed up their development. The plants will self-pollinate naturally, so care must be taken to cross-pollinate those to be crossed before the flowers open. Transfer of pollen and removal of stamens is made easier with a pair of curved, pointed forceps. Students should be reminded to clean the forceps each time they begin to pollinate a new set of flowers, to avoid contaminating the stigmas with the wrong type of pollen. Plants should be labeled as to which type of cross was made, or whether the plant was allowed to self-pollinate. These records should be retained and transferred to the containers in which the mature pods are collected. The plants should produce ripe pods in 75 to 80 days. The seeds from the ripe pods should be planted in the same manner as the parent seeds. Data regarding the parent plants should be kept with the developing seedlings. The phenotype should be evident in 5 to 10 days. Data should be summarized in a table and/or Punnett square.

Analysis and conclusions. The student's conclusions should include the idea that tallness and shortness are determined by genes, which are present in pairs. Also, tallness is dominant over the dwarf condition, and the members of a pair of genes are segregated, or separated, during gamete production and recombined during fertilization.

Chapter 10

The Genetic Material

This chapter continues with an historical approach to our gain in knowledge of heredity. The significance of chromosome behavior during cellular division is explained by comparing Sutton's findings with Mendel's work. The agreement of later workers with Sutton's hypothesis of gene linkage provides an interesting and logical sequence. Dr. Morgan's work with *Drosophila* led to the discovery of sex-linked characteristics.

If you already have presented the sex chromosomes in your discussion of probability, the background will enhance the students' ability to understand the concept of sex-linked characteristics presented in this chapter.

It is important that the students have a thorough understanding of the mechanisms of genetic change. The use of a flannel board or models in presenting chromosomal segregation may be helpful in showing these concepts in a graphic manner. If models such as various colored "pop-beads" are used, then gene linkage, nondisjunction, and crossing over can be "seen."

The concept of mutations and their causes usually requires a review of the complex structure of the DNA molecule. It is also important to point out to the students that many gene mutations may occur in somatic cells and may never be detected. For example, if a mutation occurred in one muscle cell which prevented the utilization of glycogen, the cell might die from lack of nutrition. Such an occurrence would never be detected. If, however, a mutation occurred in a gamete, the results of the alteration in genetic structure may be obvious. The fact that most mutations are recessive and that they can increase in frequency in any population will be discussed in the next chapter.

A class discussion of Beadle's and Tatum's work will be important because it not only exemplifies a scientific method, but it demonstrates the specificity of gene action. The nature of enzymes controlling specific steps of chemical reactions has been discussed in Chapter 3. The demonstration that the production of a specific enzyme is directly under the control of

DNA (the gene) was significant in the development of the "one gene—one enzyme" hypothesis. During this class discussion, the steps in arginine synthesis should be put on the blackboard. The experience of reading, discussing, taking notes, and hearing the names of various chemicals creates a familiarity of the subject which aids in retention of concepts.

P. 131, bottom right column: In answering these questions, review p. 111 and the diagram of meiosis.

P. 133, left column: In discussing Sutton's parallels, refer again to Fig. 8-7 on p. 111.

P. 137, left column: The statement that sex is determined in humans in the same manner as in the fruit fly could lead to a discussion of when the sex of humans is determined (at conception). To date there is no way of reliably determining the sex of humans prenatally or of making a choice as to the sex of the offspring. Attempts have been made with cattle to influence the sex of the offspring by changing the alkalinity of the fertilization environment at the time of mating.

P. 142: When discussing the composition of a gene, review the structure and composition of DNA and RNA, pp. 49-52.

P. 147, Fig. 10-13: How can you tell this is a genetic trait and not environmental? Plants that normally make chlorophyll do so when exposed to light.

P. 148: Explain the use of the Geiger counter as a means of measuring the amount of radiation. Radiation can be harmful when it causes undesirable mutations, or it can be helpful when used to produce new strains of an organism, as in penicillin (see pp. 250-251).

P. 145: Use Fig 10-12 to review the scientific method first presented on pp. 8-12.

Suggested Films

DNA: Molecule of Heredity (b&w&col, 16 min) EBF

Genes and Chromosomes (col, 28 min) AIBS McGraw-Hill

Genetic Investigations (b&w&col, 12 min) Ind

Heredity and the Chromosomes (b&w, 30 min) Ind

Mutation (col, 28 min) AIBS McGraw-Hill

Radiation and the Population (b&w, 30 min) Ind

MAJOR CONCEPTS

1. Chromosomes and genes occur in pairs in the zygote and in all somatic cells.
2. Chromosomes and genes segregate during meiosis, and only one member of each pair normally enters a gamete.
3. Chromosomes maintain their individuality during segregation. Each pair segregates independently of all other pairs.
4. Studies of the chromosomes of the fruit fly led to the identification of the X and Y chromosomes, which determine the sex of an offspring.
5. The traits determined by the genes making up the X and Y chromosomes are called sex-linked characteristics.
6. Abnormal chromosome segregation may occur and is called nondisjunction.
7. It is chromosomes and not individual genes that segregate during meiosis. During segregation, segments of chromosomes bearing many genes may separate and exchange with a corresponding segment of the other member of a chromosome pair. This crossing over produces unexpected results.
8. Recent studies indicate that the gene should be defined in terms of the DNA molecule. A gene may be defined as that portion of a DNA molecule that is genetically active and produces a trait—that is, it is a unit of hereditary information.
9. Mutations are errors in the genetic code. Gene mutations are more common than chromosomal aberrations or chromosomal mutations, which may be due to nondisjunction during segregation in mitosis, loss of an entire chromosome, or crossing over.
10. Although a mutant gene is nearly always recessive to a normal allele, it may also be lethal.
11. The rate at which genes mutate varies. Some mutate as often as once in 2,000 cell divisions; others mutate only once in millions of cell divisions.
12. Mutations have been artificially induced by various radiations, temperature increase, and certain chemicals.

13. Experimentation on the mutation in *Neurospora* led to the development of the "one gene-one enzyme" hypothesis of gene action.

ANSWERS TO QUESTIONS FOR REVIEW (Pages 153-154)

1. The nuclei of the egg and the sperm were of approximately equal size. Therefore, he thought that if the genetic information were contained in this structure, the combination, making a whole, must be made of two halves.
2. a. Chromosomes and genes occur in pairs in the zygote and in all somatic cells; b. chromosomes and genes segregate during meiosis, and only one member of each pair normally enters a gamete; c. chromosomes and genes maintain their individuality during segregation. Each pair segregates independently of all other pairs. This confirmed Mendel's law of independent assortment of the characteristics he observed in garden peas.
3. Since many characteristics were hereditary, Sutton believed that there were many genes located on each chromosome, and that they must segregate in sets rather than individually.
4. The genes involved in Mendel's studies were on different chromosomes and they segregated independently. The peas Mendel used had seven pairs of chromosomes, and by coincidence each of the contrasting traits he studied was determined by genes on different chromosome pairs.
5. The male and the female *Drosophila* each have three pairs of identically shaped chromosomes. The shape of the fourth pair is rod-shaped in the female, but in the male, the fourth pair is bent like a hook. These are termed the X and the Y, or the sex, chromosomes.
6. In many organisms, the presence of two X chromosomes produces a female and the presence of an X and a Y chromosome produces a male. In some organisms there is no Y chromosome, so that XX produces a female, and XO results in a male.
7. A sex-linked gene is a hereditary determiner that is carried on the X chromosome.
8. Morgan discovered that all the white-eyed flies of the F₂ generation were males. The definite association of eye color and sex led him to the hypothesis that there was a chromosome associated with sex and that this chromosome carried genes as did the other chromosomes.
9. The sex chromosomes are those (the X and Y) that determine the sex of the offspring. The remaining chromosomes are called autosomes.
10. Nondisjunction is an abnormal segregation of chromosomes.
11. Segments of chromosomes, bearing many genes, may separate and exchange with a corresponding segment of the other member of a chromosome pair.
12. A chromosome map is a diagram of a chromosome showing the location of various genes in relation to one another. Such mapping has been done for *Drosophila* and corn. Similar maps are being made to locate specific genes on human chromosomes.
13. Griffith found that noncapsulated organisms did not cause pneumonia, but that the capsule-forming strain did. He injected noncapsulated organisms plus capsulated organisms that he had killed with heat into the mice. Soon they developed pneumonia and died. He recovered living capsulated forms from the dead animals. Therefore, the noncapsulated form had been transformed in some way.
14. If you have blue eyes, for example, every cell in your body contains the gene for blue eyes. Yet only in the cells of the iris of your eyes is this trait expressed. Here the gene for eye color produces enzymes which in turn regulate the making of blue pigment. As a result of the action of many thousands of genes, you also have many thousands of enzymes controlling the chemical activities of your cells.

15. Gene mutations may be caused by radiation and certain chemicals. Chromosome mutations may occur naturally as the result of nondisjunction during segregation in meiosis, loss of an entire chromosome or piece of a chromosome, or recombination of chromosome segments by crossing over.
16. If a mutation occurs in a body cell of a plant or animal, the variation appears in all of the tissue that descends from the original mutant cell. This is a somatic mutation. If a mutation occurs in a reproductive cell, it may be transmitted to offspring. This is a germ mutation.
17. Muller used X rays to produce mutations in *Drosophila*.
18. The chemical sequence begins with a prior substance from which ornithine, a nitrogen-containing organic molecule, is formed. In a second step, citrulline is produced from ornithine. Arginine is in turn synthesized from citrulline. In each step, a separate and definite enzyme is utilized. In each step, a separate gene controls the production of each enzyme.
19. X rays altered or destroyed the gene or genes controlling the synthesis of the essential amino acid arginine.

ANSWERS TO APPLYING PRINCIPLES AND CONCEPTS (Page 154)

1. In 1903, Walter S. Sutton, a young graduate student at Columbia University in New York, presented a hypothesis of significance. He proposed that hereditary particles, or genes, are component parts of chromosomes. This was the first reference to the gene as the determiner of a genetic characteristic.
2. In raising *Drosophila*, they found one fly that had white eyes instead of the normal red eyes. The fly was a male and was mated with a normal red-eyed female. All the F_1 generation had normal-colored eyes. Thus the assumption was made that red eye color was dominant over the white eye color. When the F_2 generation

- was examined (after mating the F_1 flies), several white-eyed flies were found. However, all the white-eyed flies were males. This led to the discovery of the sex-chromosomes and to the fact that there were sex-linked characters carried by the genes on the sex chromosomes.
3. The zygote resulting from a division in which nondisjunction had occurred is either missing many genes or has duplicate genes. In either case the abnormality is likely to bring about the death of the developing organism.
4. Genes determine hereditary traits and they are portions of DNA molecules. DNA acts through messenger RNA, which in turn encodes amino acids to synthesize proteins. Therefore, anything which would change the chemical nature of any of the groups in the DNA molecule would alter the function of the gene. Any change in the base coding of a DNA molecule would alter or destroy the trait associated with the gene.
5. Transformation proves that the gene is DNA, and it demonstrates that genes can be transferred from one organism to another and continue to express their genetic qualities.
6. Muller reasoned that lethal mutations would be the most likely to result from radiation. By radiation of the sex chromosomes he found that the radiated X chromosome bore a lethal gene that prevented the males from developing. The females that possessed one normal X chromosome as well as one radiated X chromosome did develop because of a dominant gene present on the normal X chromosome.
7. Radiation destroyed the mold's ability to synthesize arginine. Since the synthesis of arginine involves three steps, it was hypothesized that an enzyme was needed for each step and that a separate gene was responsible for the formation of each enzyme. By adding the different compounds to the culture media of various mutants, they found that their reasoning had been correct, and that a different gene was involved in each chemical step.

8. If the mold grew when citrulline was added to the medium, you would know that the enzyme was present that converted the citrulline to arginine. If the mold grew when ornithine only was added to the medium, you would know that the enzymes for the conversion of ornithine to citrulline and the conversion of citrulline to arginine were both present—and therefore the genes controlling the production of these enzymes. If the mold grew when

only the prior substance in the medium was present, then you would know that all the enzymes were present for the synthesis of arginine and that none of the genes involving the synthesis of arginine had mutated. However, if the mold failed to grow in any of the above experiments, then you could surmise that the gene controlling the production of that particular enzyme was the one that mutated.

Guide to Laboratory Investigations for Chapter 10

INVESTIGATION 10-1

Chromosomes and Genes

Scope of the Investigation This Investigation enables the student to observe chance distribution as it occurs in the distribution of genes during fertilization (pp. 112, 127) by use of a simple demonstration. If the student pursues Part 2 of this experiment he will have a unique opportunity to observe actual chromosomes which he has removed from a living organism.

Approximate time required In Part 1, selecting the beans in several rounds and tabulating results should require approximately 30-40 minutes.

A capable student should be able to complete Part 2 in a period of 50-60 minutes. It is possible that additional time could be required if the student has difficulty with the technique.

A Part 1 Demonstration of the Chance Combination of Genes During Fertilization

Suggestions for procedure. Eight boxes containing 1,600 red beans and 1,600 white beans are needed for this demonstration. To insure random selection, red and white beans should be of the same size and shape. Some white beans can be dyed red to insure uniformity. Colored pieces of paper may be used instead of the beans. Students should form four groups, and each student take his turn selecting, without looking, one bean from each of the two boxes containing 400 red beans and 400 white ones. The rounds should vary in length, from two to five minutes. The students must be certain to place the beans in three rows: red-red, red-white, and white-white. Beans picked in each round may be left on the table for visual comparison with the results of the other rounds, as long as there are enough beans left in the boxes to insure random selection. The teacher should direct the calculations at the end of each round, pointing out Fig. 10-1-a as an example. The beans may be protected against insects and stored for use another year if a few moth balls are added to the storage containers.

Student observations—answers to questions.

- (a) Should approximate a 1:2:1 ratio.
- (b) Chance selection is not interfered with.
- (c) Chance selection is not interfered with through imbalance of colors present in any one box.

- (d) Large samples are more reliable in obtaining ratios.
- (e) 50:50.
- (f) 50:50.
- (g) Each color represents one of the gene pairs.
- (h) Chance distribution and combination of genes; law of segregation.

Interpretation. Chance selection of genes allows for recombination of traits in the offspring, with the number of possible combinations being directly proportional to the number of chromosomes and genes in the cells of the organism.

B Part 2 Study of Salivary Chromosomes in *Drosophila*

Suggestions for procedure. This Part is designed for the more capable student or perhaps as a demonstration by a group. The student should be provided with a culture of fruit fly larvae, carmine powder, 45% acetic acid, and 0.7% sodium chloride solution. Note that plastic cover glasses are essential in this exercise. The largest larva should be selected for dissection. A hand lens or tripod magnifier will be necessary to see the parts distinctly. A dissecting microscope is ideal. The head of the larva should be pierced with a dissecting needle as near the tip of the head as possible, in order to remove only a small piece of the head. After the head is successfully pierced (this may require several attempts), the tail should be pierced, and the mouthparts removed according to the instructions in the student manual. The mouthparts should be observed under the microscope and the salivary glands isolated, stained, and prepared for observation as outlined in the student manual. The various steps in the preparation are often difficult for the student, and he may find it necessary to make several attempts at removing the salivary glands and releasing the chromosomes from the nuclei.

Student observations—answers to questions.

- (a) The gland is crushed and some of the cells are separated from each other.
- (b) Probably will be evident.
- (c) May see bands on the chromosomes.
- (d) It probably will appear as a long flexible rod.
- (e) No, though some bands probably can be seen.

Interpretation. The chromosomes are very large, and there are only four pairs present.

INVESTIGATION 10-2

Crossing Fruit Flies to Study Heredity

Scope of the Investigation This investigation is designed to guide the student in the processes of culturing and crossing fruit flies. In the course of this Investigation the student will make crosses of flies of undetermined genetic make-up, and attempt to determine the genetic nature of various physical characteristics. By crossing flies with special traits, the student can illustrate the Mendelian laws he studied on pp. 116-128 of the text.

Approximate time required This Investigation is a long-range project which will require several weeks to several months, depending on the number of generations studied.

B Part 1 Genetic Crosses in Fruit Flies

Suggestions for procedure. Their short life cycle, ease of culturing, and obvious genetic differences make the common fruit fly, *Drosophila melanogaster*, an ideal subject for genetic studies. Materials necessary for this study include a culture of the wild-type *Drosophila*, 25 culture jars (8 oz., 2 oz., or half-pint milk bottle), two 4-oz. jars, cotton plugs and caps, camel's hair brush, a nail, autoclave, refrigerator, ether, ripe banana, cake yeast, nutrient agar, cornmeal, and corn syrup. Media for the cultures should be prepared by students according to the instructions in the student manual. Note that a piece of filter paper or paper toweling must be inserted in each jar to provide an area for the flies to crawl on and pupate. When the flies have been collected, they should be kept at about 75°F, and out of bright light. The flies will do well at room temperature. If the room is quite warm, the flies will develop rapidly; their life cycle will take somewhat longer in a cool room. Care must be taken to avoid mold contamination of the cultures. Thorough sterilization of all jars, caps, cotton plugs, paper strips, and media will be of value, as will rapid transfer of flies to avoid the introduction of airborne spores. Transfer of established molds to subcultures can be avoided if treated pupae are transferred, rather than adult flies. Pupae can be treated by washing them in a wine-colored solution of potassium permanganate. Also, commercial mold inhibitors can be obtained from a biological supply house and added to the media.

In examining and sorting the flies, they must be etherized. An ether bottle can be constructed as outlined in the student manual, using a nail or piece of wire to attach the cotton to the cork. Students should be cautioned strongly against improper use of ether. It should never be used in a room with an open flame, as it is extremely flammable. The flies should be etherized within 10 seconds. Students should be careful to avoid over-etherizing the flies, as they are quite sensitive. The flies should remain inactive for about five minutes. If some flies need to be re-etherized, this can be done by covering them for a few seconds with an inverted Petri dish which has a tiny strip of ether-soaked paper taped inside.

Sorting the flies should be done with a camel's hair brush on a clean white background. Distinguishing between the sexes may require a bit of practice. Students should practice on adults from stock cultures before the mated flies begin to appear, so they will be able to work quite rapidly when necessary. Characteristics and methods of identification are discussed in the student manual. If the flies are to be retained for further experimentation, they should not be left in the ether too long, nor should they be exposed to the heat of a very bright light.

It is essential that experimental matings be made with virgin females. It should be assumed that any females over 12 hours old have already mated and therefore cannot be used for experimental matings. Therefore, newly hatched adults should be etherized, sorted, and the sexes separated before they are 10 to 12 hours old. Pairs of males and females selected for specific crosses should be removed at this time and put in separate jars and allowed to mate and lay their eggs. It is suggested that three jars be prepared for each cross to be sure that one will obtain a successful mating. Cultures of white-eyed males, red-eyed females, red-eyed males, and white-eyed females should be retained for Investigation 10-3, Part 3.

Student observations—answers to questions.

- (a) Answers will vary.
- (b) Answers will vary.

Interpretation. Red eyes, long wings, and a gray body are dominant characteristics in the wild-type *Drosophila*.

INVESTIGATION 10-3

Sex Chromosomes and Linkage

Scope of the Investigation This Investigation is designed to aid the student gain a further understanding of sex determination, which he studied on p. 136 of the text, and sex-linked inheritance, which is discussed on pp. 137-139 of the text. Part 2 approaches the problems of sex-linkage and gene action through a laboratory demonstration, while Part 3 uses fruit flies to illustrate the inheritance of sex-linked traits (pp. 134-139).

Approximate time required The average student should be able to complete Part 1 within 10 minutes.

Part 2 will require approximately 90 minutes if the hour for soaking the pipe cleaners is included in class time. The pipe cleaners could be prepared prior to the class time, or could be soaking while the students are engaged in another activity. Use of the indicator and analysis of the resulting color changes should require about 30 minutes. Part 3 is a long-range project which will require at least three weeks.

A Part 1 Sex Chromosomes

Suggestions for procedure. This Part is a simple workbook-type exercise in which the students follow the instructions in the student manual.

Student observations—answers to questions.

- (a) XX.
- (b) Xy.
- (c) 50%.
- (d) 50%.
- (e) There is no way to determine whether the X or y sperm will be involved in fertilization.

B Part 2 Study of Sex Linkage

Suggestions for procedure. Students should prepare the pipe cleaner “chromosomes” and place them in the proper solutions. The straight pipe cleaners in the 10% HCl will represent X chromosomes bearing the dominant *C* gene for normal color vision, while those in the 1% NaOH will represent the X chromosomes bearing the recessive *c* gene for color-blindness. The bent pipe cleaners are the Y chromosomes and are not placed in either solution, for they carry no genes for color vision or color-blindness. The pipe cleaners are to be soaked for about an hour, and should be left in the solutions until they are ready to be used, for some may turn brown if they dry out. It is important that the brom thymol blue be a weak solution and in its transition color, which is a blue-green. About as much brom thymol blue as will stick to half a wet toothpick dissolved in 500 ml of hot tap water in a large flask should be sufficient. If the solution is not in its blue-green transition color, it may be adjusted as follows. Dilute a few drops of the 1% base about 10-fold, and a few drops of the 10% acid about 100-fold. Add a drop of the dilute base to the indicator solution. It should turn a deep blue. If it does not transmit light, it is too concentrated and should be diluted. Next, add a few drops of the dilute acid until the indicator turns bright yellow. Then swirl the contents vigorously, adding the dilute base 1 drop at a time until the indicator turns the blue-green color. If you go past this point, add a drop of the acid. If the indicator seems to go directly from blue to yellow and back, the acid and base solutions are too strong and should be diluted further. It is essential that the indicator be in its transition color when supplied

to the students. Four test tubes should be filled with the indicator and labeled, representing the "cytoplasm" of four "cells." The pipe cleaner "chromosomes" should be distributed to the "cells" as directed in the student manual, and the solutions observed for any change in color. Results and conclusions should be recorded in the table. The second cross is carried out in a similar manner.

Student observations—answers to questions.

- (a) 50%.
- (b) None.
- (c) Since color-blindness is a recessive trait, it would not appear in the female in the presence of the dominant gene for normal color vision. Since the male has only one X chromosome, there is no possibility of his having a normal gene to mask his gene for color-blindness.
- (d) 50%.
- (e) The X chromosome from the father would bear the gene for color-blindness. One-half the X chromosomes from the mother would also bear this gene.
- (f) 50%.
- (g) One-half the X chromosomes from the mother would bear genes for color-blindness.

Interpretation. This could result only if the father were color-blind and the mother were either color-blind or a carrier of the gene. The chances of such a marriage are rare.

C Part 3 Study of Sex-Linkage in Fruit Flies

Suggestions for procedure. The procedure for culturing, handling, and mating fruit flies is outlined in Investigation 10-2. Similar apparatus will be required for this study. Crosses should be made according to the outline in the student manual, and the offspring observed for sex and eye color. Note that at least 100 F_1 flies and 150 F_2 offspring should be examined.

Analysis and conclusions. The student should include among his conclusions the facts that red eyes in *Drosophila* are dominant over white eyes, and that the genes for eye color are sex-linked; that is, carried on the X chromosome.

INVESTIGATION 10-4

Gene Action

Scope of the Investigation This Investigation is designed to aid the student in understanding how genes exert their influence on cells and organisms. The concept of "one gene—one enzyme" (pp. 149-153) should arise from this study, in that the students should see that genes cause chemical differences and chemical differences cause physical differences. Also, the students should observe that even though certain genes are present, they require the proper environment before they can exert their influence (pp. 144-146).

Approximate time required The average student should be able to complete Part 1 within a 50-60 minute period after the peas have soaked 24 hours. Part 2 should require 80-90 minutes after the agar mixture is prepared. Part 3 is a rather long-range project which could require several weeks.

A Part 1 Gross Differences in Smooth and Wrinkled Peas

Suggestions for procedure. Smooth and wrinkled peas, 30 each, are required for Part 1. These peas should be weighed, soaked 24 hours, and reweighed as instructed in the student manual. Note that the seeds should be blotted dry before weighing.

Student observations—answers to questions

- (a) The smooth peas exhibit no visible change, other than a slight swelling. The wrinkled peas swell and smooth out.
- (b) The wrinkled peas.
- (c) They took up a great deal of water.
- (d) The wrinkled peas.
- (e) Internal differences—the nature of the stored materials.
- (f) Oval.
- (g) Bilobed, with a constriction in the middle.
- (h) Yes.
- (i) The nature of the starch grains is determined by genes. Thus, they are the same in all the wrinkled peas or smooth peas.

B Part 2 Chemical Differences in Peas

Suggestions for procedure. The agar and glucose-1-phosphate mixture should be boiled until the foam looks coarse, and poured according to instructions in the student manual. The peas should be ground, a few at a time, until they are in powder form, and can be added to water to form solutions. Several layers of cheesecloth can be used to filter these solutions. Both extracts should be labeled. Note that the mortar and pestle used each time is clean so that it is free from powder of the other seeds. Drops of the two extracts should be placed on the surface of the agar plates, as stated in the student manual. Thirty minutes should be allowed for the extract to act on the agar. (This time may be reduced if the plates are incubated at 37°C.) Iodine should then be used to test the reaction, and the excess starch grains removed. A second test should be made after 60 minutes.

Student observations—answers to questions.

- (a) A blue ring is formed.
- (b) A darker blue, more dense ring is formed.
- (c) Yes.
- (d) Starch.
- (e) The wrinkled peas formed more starch.
- (f) The wrinkled peas have more of the enzyme that converts glucose-1-phosphate to starch.

Interpretation. The chemical properties of the two types of peas differ, in that they do not form starch in equal amounts. Thus they must differ in their enzyme content. The enzyme production is controlled by genes in the peas. Students could pursue this one gene—one enzyme hypothesis. In this Investigation they are dealing with only one characteristic, but it leads the way for a discussion of many others, all based on the same idea.

C Part 3 Influence of an Environmental Factor on Gene Action

Suggestions for procedure. Students should be provided with seeds of genetic corn produced from a cross of parents known to be heterozygous for albinism. (Thus one in four of the offspring would be albino.) Seeds should be planted, covered and uncovered, according to the instructions in the student manual.

Analysis and conclusions. A specific gene is responsible for chlorophyll production. Lack of this gene results in albinism. However, light is necessary for the production of chlorophyll even if the normal gene is present.

Chapter 11

Genes in Human Populations

This chapter expands the treatment of factors controlling heredity on an organismic level to include populations. It is one thing to determine the probability of an offspring having blue eyes, but quite another to calculate the probability of a certain percentage of a population having blue eyes. In the former, we are concerned with the genes in gametes of two parents, but in the latter, we must be able to calculate the frequency of the gene in the population.

One of the most obvious questions from the students will regard the method by which gene frequency can be computed. Thus, a discussion of obtaining data by sampling is advisable. Point out that a survey of blue eyes in the class would not be a sample that would enable a reliable estimate to be made of the school, the community, the county, or the state. In conducting a sampling, then, the accuracy of a prediction will depend on the selection of a representative group. Though one class may not be an accurate representation of a large area, you may still use the ability to taste PTC paper or tongue-rolling to launch a discussion.

The development of twins is always of interest to high school students. The differences in genetic makeup between fraternal and identical twins forms a basis for a discussion on the comparison of similarities and differences of the two types of twins.

The effect of multiple alleles is easily shown by the four different blood groups with which the students are already familiar. Using the symbol *I* to represent all three of the genes and the letters *A*, *B*, or *O* to represent the agglutinogens produced, several problems should be given until you are satisfied with the pupils' understanding of the genetic influence in the formation of blood types. Be sure the students list the probabilities expected in each cross.

It is suggested that additional problems dealing with sex-linked characteristics (such as color blindness and hemophilia) also be given. Many students find these problems confusing at first, but when they understand segregation and recombination of the chromosomes, the problems become simple. Green and yellow lentils may provide good visible models to represent the X and Y chromosomes. When a sex-linked characteristic is to be considered, a pencil mark will readily indicate this recessive gene on the lentil.

P. 155, right column: A discussion of the age-old question of "nature vs. nurture" might stimulate interest here. Such questions as, Why does musical ability seem to run in families—is it a genetic ability or simply the cultural heritage and emphasis in the family? might provoke interest. In general, eugenicists seem to agree that heredity and environment are in constant interaction and about equally significant.

Another difficulty in studying human heredity, not discussed here, is the fact that it is not possible to arrange particular crosses in human beings to study the results. Students might be led to reach this conclusion.

P. 156, left column: Here is a good place to review gametogenesis (p. 110), so that students can understand that it is purely a matter of chance which member of a chromosome pair enters which gamete in meiosis. It is also purely a matter of chance which chromosomes each parent received from his parents. It has been said that there are 70 trillion possible combinations of genes that can appear in a given individual.

Fig. 11-1: Draw attention to the difference in the sex chromosomes, as sex determination has been discussed on p. 136.

P. 157: In discussing the PTC trait, you might emphasize that it is not possible

to detect the presence of a recessive gene in a heterozygous individual. Thus if a serious hereditary disease is carried by a recessive gene, as is cystic fibrosis, the trait will be masked in the parents and show up only if the child receives a gene for the trait from each parent.

P. 158, right column: Since various ethnic groups are discussed here, you could point out that although gene pools are recognizable in various parts of the world, there is considerable intermingling, especially in the modern world. Although certain characteristics are more prevalent among various ethnic groups, no group of men have any characteristics that are totally absent in other groups.

P. 161: In the discussion of blood types, you may want to refer at this time to further material on agglutination (see pp. 586–587).

P. 163: Students may need practice in making various possible crosses involving the color-blindness gene. They may be led to see that, fortunately, it is quite unlikely that a female will receive two recessive genes for baldness.

P. 164: Female hemophiliacs are rare and usually die at the onset of menstruation. It is interesting that the trait not only was carried by Queen Victoria, but has been quite common throughout the royal families of Europe, as there is so much intermarriage. Recently doctors have been able to supply the missing protein to hemophiliacs in an emergency.

P. 165, Fig. 11-7: Go over the diagram so students understand how the interrelationships are indicated. Have students pick one characteristic and trace it through as many relatives as possible. Encourage originality in preparing the chart. Some may indicate the trait by drawing eye color while others may indicate it by skin color. Give sufficient time so data can be gathered (with reminders). Unknowns may be indicated by relationship but with the trait indicated by a question mark. Some students will give only a few family members and some may go as high as 70! Physical traits and others like musical ability may be chosen.

P. 166, left column: Point out that whether a susceptible person actually develops allergies, bronchitis, etc., may de-

pend on environmental conditions such as the emotional climate in the family, diet, and rest.

P. 167, Fig. 11-8: This photograph affords an excellent example of non-disjunction (review pp. 139–140). Chromosomal aberrations, along with gene mutations, seem to be a major factor in variation and resulting evolution, which will be discussed in Chapter 13.

P. 168: Recently doctors have found that if phenylpyruvic idiocy is discovered in the first few weeks of life, a carefully controlled diet may arrest the condition.

Suggested Films

Blood Groups (col, 28 min) AIBS McGraw-Hill

Inheritance in Man (col, 28 min) AIBS McGraw-Hill

It Runs in the Family (b&w, 30 min) Ind

Many Pairs of Genes (b&w, 30 min) Ind

MAJOR CONCEPTS

1. The almost limitless number of human hereditary traits is produced by the action of an enormous number of genes on the 46 chromosomes in every body cell.
2. By determining the frequency with which a given gene appears in a population, it is possible to predict the probability of the appearance of a given genetic trait in offspring.
3. Gene frequency in a population is obtained by conducting a poll involving a particular genetic trait and including a large enough sampling to be considered significant.
4. Various populations show evidence of a high frequency of certain genes, but gene pools change as populations shift.
5. Fraternal twins develop from separate eggs which are fertilized by different sperm.
6. Identical twins develop from a single fertilized egg which has separated after the first division. Therefore, they have identical genetic makeup.
7. Certain traits, such as blood types, are the results of the interaction of several pairs of genes. In any one individual, however, the blood type is the result of only two.
8. Color-blindness and hemophilia are

examples of sex-linked genes in the human.

9. Some traits, such as baldness, are sex-influenced as they are dominant in males but recessive in females.

10. Some traits, such as the bright plumage of male birds, are sex-limited. The genes may occur in both sexes, but the characteristics appear only in the presence of sex hormones.

11. Some diseases resulting from abnormal structure or function of body organs may be hereditary.

ANSWERS TO QUESTIONS FOR REVIEW (Page 169)

1. Shape of nose, eye color, hair color and texture, height of forehead, height and general build of your body, shape and size of ears.
2. Population genetics is the study of how frequently given genes appear in a population.
3. The ability to taste PTC is inherited. To those who can taste, it is bitter. Since the ability to taste is a dominant gene, a taster may be heterozygous. A nontaster is homozygous recessive. Therefore, by testing the tasting ability of a group of people for PTC, the frequency of the gene in the population may be determined.
4. The gene pool refers to all the genes present in a given population.
5. A gene pool may be considered stable only when individuals are not entering or leaving a population.
6. Fraternal twins develop from separate eggs which are fertilized by different sperm. They are no more alike genetically and no more closely related than other brothers or sisters in a family. Identical twins started life as a single fertilized egg. After the first division, the two cells separated and started growth again, resulting in twins. Identical twins, therefore, have identical genetic makeup.
7. A and B red corpuscle agglutinogens or the lack of any agglutinin (O) are under the control of three genes. Only two genes are present in any one person. a. Genes AA or AO produce type-A corpuscles; b. genes BB

or BO produce type-B corpuscles; c. genes OO produce type-O corpuscles (no agglutinin); d. genes AB produce type-AB corpuscles (both agglutinogens).

8. Multiple alleles are three or more genes that act together to produce a specific trait.
9. Three genes control the blood type. In any one person, only two of these alleles are present. See the answer to question 7.
10. There are believed to be as many as four pairs of alleles that determine the Rh factors. Humans having corpuscles that contain the Rh factor are Rh positive. People who lack the factor are Rh negative.
11. The genes associated with red-green color vision are located on the X chromosome, and the gene for normal vision is dominant. Since the female (XX) has another allele it is less likely that both the genes would be recessive for the trait. The male (XY) only has one gene for the determination of color vision, so if it is recessive, it is expressed. Therefore, this sex-linked characteristic is found more often in the male.
12. Hemophilia is a condition in which a blood substance necessary for clotting is not produced because of lack of the gene necessary for its formation. Therefore, a bleeder may die from loss of blood as a result of a very slight wound. Since hemophilia is caused by a sex-linked gene, it runs in families and tends to appear in males.
13. A trait produced by a gene that is dominant in males but recessive in females is said to be sex-influenced. Baldness is an example. A trait that appears in one sex or the other, but not in both, even though the genes are carried in both sexes, is said to be sex-limited. An example is the bright plumage of the male bird as contrasted to the duller colors in the female, even though the same genes may be present in each.
14. Blue pigment is produced by a single pair of recessive genes. The genes producing brown pigment are

dominant. The various shades of iris pigmentation from hazel to light brown or dark brown are apparently the result of the expression of varying numbers of genes for brown pigmentation. Other genes for pigmentation produce shades of gray ranging to green.

15. Diseases resulting from abnormal structure or function of body organs are more likely to be hereditary. An example is sugar diabetes. Other diseases that may be associated with genes are: respiratory allergies including asthma, bronchitis, nearsightedness, farsightedness, and nightblindness.
16. A score on a test that involves reasoning, memorizing, calculating, visualizing, word recognition, word usage, and other fundamental thought processes is used to determine the *mental age*. Intelligence is then determined by dividing the mental age by the *chronological age*, or age in years. The result is multiplied by 100 and is called the *intelligence quotient*, or I.Q.
17. The normal chromosome number in humans is 46, but the body cells of some individuals contain 47 chromosomes, while others have only 45. When the body cells of Mongolian idiots have been examined, there have always been 47 chromosomes present. Mongolian idiocy, then, seems to result from the presence of an extra chromosome, resulting from nondisjunction during meiosis.
18. Phenylpyruvic idiocy is due to the lack of an enzyme that converts the amino acid phenylalanine to a similar amino acid, tyrosine. The condition is inherited as a simple recessive trait.

ANSWERS TO APPLYING PRINCIPLES AND CONCEPTS (Page 169)

1. Although genes are determiners for such things as stature, height, shape of nose, etc., the environment also makes its mark. A person's face, for example, reflects worry, contentment,

general health, emotional stress, and nutrition. Environmental influences may prevent the development of the potential inheritant in genes.

2. With each generation the number of a person's ancestors doubles. A family history might be made, but the living relatives represent only a small sampling. Except for certain easily recognized traits, data concerning ancestors is usually vague and unreliable. Do you know, for example, the blood type of your great-great grandfather?
3. In any quantitative study dealing with populations, the accuracy of the work depends on the selection of a representative group of people. If you were going to make a determination of the average I.Q. of the American people, for example, you wouldn't compute the results after surveying all the colleges of the area. The national population includes people of all ages, educational backgrounds, professions, trades, businesses, social backgrounds, races, cultural backgrounds, and economic levels. Your sampling, then, must include people from all these groups and about equal numbers of men and women.
4. Gene pools change as individuals enter or leave a population and new gene combinations occur.
5. Having started life as the same cell, identical twins have identical genetic makeup. Therefore, identical twins show a marked likeness in appearance, temperament, abilities, likes and dislikes, and many other personality traits. Differences may be attributed to environmental influences. Identical twins then, provide us with valuable information regarding both genetic and environmental influences.
6. The basic capacity for learning has been studied in identical twins. While they may vary somewhat in intelligence as determined by scores on tests, these differences indicate the influence of different environments rather than in basic capacity for learning. The opportunities for studies of identical twins in different environments are very limited.

7. Phenylpyruvic idiocy is due to the inability of the individual to convert the amino acid phenylalanine to a similar amino acid, tyrosine. The enzyme necessary to convert phenylalanine to tyrosine is present in the liver of normal individuals. The condi-

tion is inherited as a simple recessive trait. It also illustrates the vital role of enzymes in growth and development, since only one pair of genes and the lack of one enzyme prevents the phenylpyruvic idiot from developing as a normal individual.

Guide to Laboratory Investigations for Chapter 11

INVESTIGATION 11-1

Frequency of Human Genetic Traits

Scope of the Investigation Human genetics obviously cannot be studied by making experimental crosses to determine the genetic nature of certain characteristics. Thus human genetics studies generally depend upon population genetics—the determination of how frequently certain genes appear in a given population (pp. 155-158). Parts 1 and 2 of this Investigation enable students to conduct such studies on a limited scale by determining the frequency of PTC tasters and tongue rollers in their families and community. Part 3 guides the student in a further study of the genetic determination of human blood types, which he studied on pp. 160-162 of the text.

Approximate time required Taking the survey information for Parts 1 and 2 will be done outside of class, either overnight or over a weekend. Tabulation and analysis of results should require 30-40 minutes of class time.

Part 3 should take the average student approximately 30 minutes.

A Part 1 Inheritance of the Ability to Taste Phenylthiocarbamide

Suggestions for procedure. PTC papers for this study can be obtained from a biological supply house. Students should taste these papers and have their families taste them, not telling their families what to expect from the paper. From the tabulated results, students should be able to determine whether the gene for tasting PTC is dominant or recessive.

Student observations—answers to questions.

- (a) Probably yes.
- (b) Dominant.
- (c) No.
- (d) Neither parent could contribute a dominant gene for tasting to the offspring.
- (e) Yes.
- (f) One parent must have a dominant gene for tasting if he is a taster, and he can contribute this gene to the offspring who is also a taster.
- (g) Yes, it is possible.
- (h) If the parent who is a taster is heterozygous for the trait, he can contribute the recessive gene to the offspring.

A Part 2 Inheritance of the Ability to Roll the Tongue

Suggestions for procedure. Students should survey their families and others in their community for the ability to roll the tongue. Be certain that no one person is surveyed more than once for this will alter the results. Results should be recorded in the table provided.

Student observations—answers to questions.

- (a) Answers will vary.
- (b) Probably the sample was not large enough. If any of the people surveyed in the neighborhood were related, this would alter the ratio.
- (c) Probably not.
- (d) If they had a parent who was a nonroller, they would be heterozygous.

A Part 3 Inheritance of Blood Types

Suggestions for procedure. Students should follow the instructions in the student manual for completing the table and answering the questions.

Student observations—answers to questions.

- (a) No.
- (b) A child of a certain blood type could belong to several different combinations of parents.
- (c) Yes.
- (d) If the child had a blood type produced by a gene that neither parent possessed, he could not be their child.
- (e) A number of different possible gene combinations could produce a child with a given trait. However, a child with a certain trait could not be the offspring of parents who do not possess the genes for that trait.

Chapter 12***Applied Genetics***

The study of plant and animal breeding shows the extent to which we apply the principles of heredity in commercial growing and livestock production. Nearly all students are familiar with many highly developed breeds of farm animals, varieties and strains of hybrid crop plants, hybrid roses, and other hybrid plants grown today.

Many people associate plant breeding with the work of Luther Burbank. We recognize his contributions to plant breeding in the opening portion of the chapter. Hybridization, or outbreeding, and line breeding, or inbreeding, are explained. We have used the double-cross method of producing hybrid corn as an example of both inbreeding and hybridization methods employed by the growers. We explain bud mutations and increase in chromosome numbers as sources of many new varieties of plants.

In the discussion of plant development in this chapter, seed catalogues can be used to good advantage. Seed companies are some-

times willing to send sufficient copies for class use if the teacher states the purpose of ordering in bulk. The catalogues illustrate the practical application of plant genetics. New varieties are listed such as tetraploid snapdragons and F_1 petunias. Also stressed are traits for which plants have been bred (such as wilt resistance). A catalogue increases the student's vocabulary and acquaints him with many kinds of plants available to men as food or decoration. Plant origins could be reported on by students to emphasize the contributions of plants to man's culture and the tremendous changes made by man in these plants. By using pictures, slides, board diagrams, and specimens from the market, the contrast between original forms and present forms becomes clearer to the student. A good example would be the Idaho potato contrasted with the original South American form of potato. Economic botany texts, back issues of *Scientific American*, and the Superinten-

dent of Documents, Washington, D.C. 20025 are sources of information on both plants and animals. Students from rural areas or those who have spent summers on farms may be able to contribute to the knowledge of applied genetics. Today valuable bulls need no longer be transported for breeding. Instead the preserved sperm are used. Students may be familiar with this or other procedures now used to improve stock.

Interesting reports on animal breeding can be given by students who have experience in the field. Especially in the southern states, the cross between the Brahman and the Aberdeen Angus should be studied. For further enrichment study, we suggest the examination of registration papers for registered cattle, horses, dogs and other animals. Long-range projects might include breeding mice, rats, or guinea pigs and experimental hybridizing of iris and other plants.

P. 172, Fig. 12-2: Point out the use of a brush for the transfer of pollen. Hand dusting can also be used for date palms, where the stamens are brushed over the female flowers. Artificial pollination in these trees serves another purpose. Because irrigated land is valuable, and since only female plants produce dates, the number of male plants needed to fertilize a whole orchard is very small.

P. 173: Burbank used vegetative propagation for his potatoes. By using portions of a plant having desired characteristics, it is possible to graft these pieces onto other stock which may be more hardy and numerous. To stimulate student thinking ask how more seedless orange plants are obtained. How can a person have several varieties of apples even if he has room on his property for only one tree? By grafting he can also have both apples and pears on the same tree or get three colors of flowers of the same species on the same shrub. One such example is the rose of Sharon. Hybrid roses are grafted onto hardy stock like multiflora.

P. 174: Gardening sections in newspapers contain articles that might be used for class discussion. In spring, especially, new varieties of plants are presented to the public for that season's planting.

P. 176: If specimens of California

navel oranges, Delicious apples, nectarines, or other specimens are brought to class, this makes the section on bud mutations more interesting to the students.

Suggested Films

Genetics: Improving Plants and Animals (b&w&col, 13½ min) Cor
Heredity and the Chromosomes (b&w, 30 min) Ind

MAJOR CONCEPTS

1. With the development of genetics as a science, established laws have greatly improved the efficiency of selective breeding of plants and animals.
2. Mass selection is used for obtaining desirable varieties as well as to produce disease-resistant strains in plants.
3. Hybridization is a rapid way of getting desired results by combining characteristics of two unlike but closely related parents in a new individual by artificial cross-breeding.
4. Line breeding involves preserving desirable characteristics by self-crosses.
5. New plants may be produced by crossing different species or by carefully propagating mutations.
6. Large fruits are produced by polyploid plants.
7. Polyploid plants may be artificially produced by the drug colchicine.
8. The principles used in plant breeding also apply to animal breeding and have been used for the improvement of livestock.

ANSWERS TO QUESTIONS FOR REVIEW (Page 180)

1. Plant breeding is practiced to produce more desirable varieties, to produce disease-resistant strains, to extend crop-growing areas with new varieties, and to produce entirely new varieties of plants.
2. Line breeding is practiced to establish a pure strain of plant or animal.
3. In hybridization, unlike parents are used. This practice produces many variations in the offspring from which desirable ones may be selected. In line breeding, plants may

be self-pollinated and animals may be bred back to parents or to close relatives in order to avoid introducing new characteristics.

4. Four pure-line parents are involved in a double-cross to produce hybrid corn.
5. Luther Burbank produced the Shasta daisy, plumcot, pitless plum, peach plum, thin-shelled walnut, and spineless cactus.
6. Natural cross-pollination is avoided in producing hybrid corn by detasseling the plants and covering the developing ears with sacks. The desired pollen is dusted onto the silks artificially.
7. The Leghorn is a heavy-laying breed of chicken. The Plymouth Rock is a dual-purpose breed, while the Cornish is a breed noted for its table qualities.
8. Dual-purpose breeds of cattle include the Milking Shorthorn, Brown Swiss, and Redpoll.
9. The mule is a true hybrid because it is the result of a cross between two different animals, the horse and the donkey.
10. Brahman cattle are excellent for crossing with domestic breeds because they endure hot, humid climates and resist insects in these climates.

ANSWERS TO APPLYING PRINCIPLES AND CONCEPTS (Page 181)

1. If offspring become weakened through continued line breeding, new and unrelated strains should be introduced. This produces hybrid vigor and prevents undesirable recessive traits from appearing.
2. Seed produced from hybrid corn will not produce other generations like the original hybrid because of its mixed parentage. The seed must be produced from known pure-line parents.
3. For the most part, 300-egg strains of poultry have been produced by mass selection. Only chickens with excellent egg-laying records and males from these strains are used as breeding stock.
4. Pedigree and registration papers are important in breeding high quality livestock as a means of determining the exact ancestry of an animal to be used in breeding. These papers are proof of pure-line ancestry. They show the relationship of breeding animals and may, by listing all parent stock for several generations, give the livestock breeder an indication of certain characteristics he may expect in the offspring.

Chapter 13

Organic Variation

Profusely illustrated articles on the origin of the earth and the changes in its plant and animal populations through the ages have aroused public interest in the content of this chapter. How did the earth appear in the dim past? What kinds of plants and animals, long extinct, flourished in early times? These are topics of great interest to most students.

Modern explanation of the phenomena causing evolution involves an understanding of the principles of genetics. Biologists believe that changes are still occurring today by way of alterations in genetic and chromosomal structure as well as by re-

combination. Industrial melanism is described as a graphic example of an observed recent change in a moth due to natural selection.

Several outstanding scientists of past years attempted to explain the mechanisms involved and the causes of the changing plant and animal populations. This chapter offers an opportunity for the teacher to point out the value of hypotheses. For example, even though Lamarck's theories are now considered to have been based on false concepts, they stimulated interest and discussion through which modern and more acceptable explanations have been derived.

Each of his ideas should be discussed, and the students should be able to point out the fallacies in his thinking in terms of what we know about biology today.

Darwin's theories were more nearly correct. Students can apply his ideas to conditions today and explain why some organisms thrive while others diminish in number or become extinct.

Examples of changes in organisms may be drawn from the familiar plants and animals around us. Why are certain trees common while others are rare? What birds and animals may become extinct in our time and why?

If fossils are found in your region, a class collection might be assembled. Clay models of prehistoric animals, placed in a setting of cycads and other ancient plants, make excellent displays. Still another project is the preparation of a geological time table, showing eras and periods, each represented by drawings of plants and animals of the time.

P. 182: The fact that organisms are changing is borne out by army statistics that show the changes that have taken place over a comparatively short period of time. The ability of some students to wiggle their ears is an example of vestigial muscles.

P. 184, left column: Animals may pass through various steps in development that resemble ancestors. Use Fig. 13-4 to point out such similarities. The human embryo also goes through such stages. Science expresses this with "ontogeny recapitulates phylogeny."

In the southern United States, there is a species of lizard that is legless and is called the "glass snake." Unlike snakes, it has external ears but otherwise could be mistaken at first sight for a snake. Such a species is useful for discussing the theory of use and disuse and bringing out the fact that in science much remains to be learned.

P. 185: While bobbed tails in dogs, horses, and mice are not inherited, there is one cat, the Manx, whose bobbed tail is inherited. That organs deteriorate through disuse is a fact used to advantage in modern medicine. Formerly people who had undergone surgery were confined to bed for long periods of time. Today they are made to get up as soon as possible.

P. 186, left column: These four points can be used for discussion of modern man's attitudes. Are these statements proved or disproved by modern man's behavior? What is meant by the best adapted? How does man change the idea that only those best fitted are the ones who survive?

P. 190: Here is a good place for student reports on the processes involved when animals change color. Some change when they are transferred from one environment to another. If two green frogs are placed in jars, one with a light background and the other with a dark background and kept for some time, their color will show adaptation to the kind of background. Here students can reason through the difference between this example and the example of the peppered moth.

Suggested Films

Darwin and Evolution (col, 28 min) AIBS McGraw-Hill

Hereditary Basis of Evolution (col, 28 min) AIBS McGraw-Hill

How Living Things Change (b&w&col, 11 min) Cor

Natural Selection and Adaptation (col, 28 min) AIBS McGraw-Hill

Species: Stability and Change (col, 28 min) AIBS McGraw-Hill

MAJOR CONCEPTS

1. Evolution is the study of the changing world of life.
2. Organisms with many similarities are considered to be more closely related than those with great differences.
3. The evidence that life has changed during the history of the earth has led to many theories regarding the cause of these changes.
4. Darwin's theory of species origination by natural selection involved overproduction, struggle for existence, individual variation, and survival of the fittest.
5. De Vries explained the mechanism of change by proposing mutation as a basis for evolution.
6. Biologists today relate evolution to the following mechanisms: gene mutations, chromosomal mutations, and recombination.
7. Chromosomal changes include: poly-

ploidy, haploidy, nondisjunction, and translocation.

8. Migration may result in variation by bringing new genetic characteristics into a population. It may also result in variation if organisms are favorably adapted to new environments.

9. Industrial melanism is a demonstration of the importance of natural selection in evolution, as well as of the impact of a change in the environment on a species.

10. Physical barriers may isolate organisms, preventing groups from interbreeding, and eventually allowing new species to form.

11. Other barriers to interbreeding are variation in the mating time of two populations, structural differences that prevent mating, and differences in mating habits.

12. Speciation may result from variation, migration, selection, and isolation.

13. A population may branch out through variation and adaptation to occupy many environments. This is called adaptive radiation.

14. Adaptation to similar surroundings and mode of life may cause some animals to be similar, although they have no biological relationship to one another. This is called convergent evolution.

ANSWERS TO QUESTIONS FOR REVIEW (Page 198)

1. Fossils show us that life has changed over the history of the earth. Other evidences are: homologous structures, vestigial organs, comparison of developmental stages, present-day plant and animal breeding studies.

2. a. Theory of need—that the production of a new organ or part of a plant or animal results from a need; b. theory of use and disuse—that organs remain active and strong as long as they are used but disappear gradually with disuse; c. theory of inheritance of acquired characteristics—that all that has been acquired or changed in the structure of individuals during their life is transmitted by heredity to the next generation.

3. a. That all organisms produce more offspring than can actually survive;

b. that because of overproduction, there is a constant struggle for existence among individuals; c. that the individuals of a given species vary; d. that the fittest, or the best adapted, individuals of a species survive to transmit their traits to the next generation.

4. De Vries proposed that mutation was a basis for evolution.

5. Mutant genes are nearly always recessive. Ordinarily DNA replicates itself exactly, but occasionally an error occurs and a new genetic code results.

6. Most gene mutations are recessive, so that the characteristic does not appear until offspring with paired mutant genes occur.

7. Polyploidy, haploidy, nondisjunction, and translocation are ways in which the chromosomal structure may be altered.

8. During fertilization new combinations of chromosomes are formed as the chromosome number is restored to the diploid number. Recombination of chromosomes and genes in sexual reproduction is a mechanism second only to mutations in the production of variations.

9. Let us suppose that gene *A* mutates to gene *a* in an individual. The trait would not be expressed because it is recessive. When the pair of alleles *A* and *a* separate during meiosis, half of the gametes produced will receive *A*, while the other half will receive the mutant gene *a*. The new characteristic is, then, increasing in frequency. It is now present in half the offspring. As these heterozygous offspring interbreed, they will produce one-fourth *AA*, one-half *Aa*, and one-fourth *aa*, as in a monohybrid cross. Thus one fourth of the offspring will express the mutation.

10. a. Migration brings new characteristics into a population; b. it provides a new environment for which an organism may have favorable adaptations that may be perpetuated in offspring.

11. Corridors are land bridges that act as pathways for migrating animals.

12. A mutation occurred in the gene governing the color of the moth.
13. Temperature differences, deep canyons, rivers, oceans, deserts, and mountain ranges.
14. Isolation prevents interbreeding from occurring so that, as mutations occur, variations between two groups may become pronounced.
15. A population branches out through variation and adaptation to occupy many environments.
16. The seal and the whale both live in the sea, have flippers for locomotion, but are different from one another. The turtle also moves by flippers. Birds, insects, and bats have wings for flight, but are unrelated organisms.

ANSWERS TO APPLYING PRINCIPLES AND CONCEPTS (Page 198)

1. Such similarities often indicate common ancestry, although structural similarities may also be the result of convergent evolution.
2. Lamarck claimed that the giraffe developed a long neck because it needed one to reach the leaves of trees and that the progress of each generation in developing such a neck was passed on to the offspring. Darwin would probably have said that some giraffes had longer necks than others and that those with longer necks had a better chance to survive than those with shorter necks. The modern theory of mutations would say that a giraffe was born with a slight difference in

neck structure caused by a mutation and not present in either parent. Since this happened to be an advantage, offspring possessing this mutation had a better chance of surviving than giraffes with shorter necks. Thus, by interbreeding, the neck mutation of the giraffe became a species characteristic of the descendants.

3. The peppered moth study shows how a mutation can increase in the gene pool when it becomes favorable to the survival of a species because of a changed environment. This study is a demonstration of the importance of natural selection in evolution.
4. Mutation is a change in genetic make-up resulting in a new characteristic which may be passed on to offspring. Recombination occurs when the haploid number of alleles in the gametes unite to form the diploid number in the zygote. Interbreeding brings unlike characteristics together and increases the combinations possible. In each of these mechanisms, the offspring produced vary from the parent. If a variation is favorable to the survival of the organism, the frequency of the gene will increase. Thus natural selection can bring about the development of a particular characteristic in a species.
5. Convergent evolution is nearly the reverse of adaptive radiation. If the environment remained the same and organisms of entirely different origin evolved in a manner that resulted in certain similarities, convergent evolution is said to have occurred.

Guide to Laboratory Investigations for Chapter 13

INVESTIGATION 13-1

Variations in Organisms

Scope of the Investigation This Investigation is designed to demonstrate that although all members of a species have the same general form and size, there is still considerable variation among individual members of a species (p. 187). Furthermore, it is these variations that provide the basis for natural selection, as the student has seen on pp. 186-190 of the text.

Approximate time required If all the students of the class work together in groups in making the measurements, they should be able to complete this Investigation in a period of 50-60 minutes. If the work is done by an individual student, it may take him 2 to 3 hours.

B Part 1 Variations in Plant and Animal Structures

Suggestions for procedure. Note that the grasshoppers are to be either all male or all female, and all of the same species. If the insects are preserved, the joints tend to become stiff. Thus the students should be cautioned against trying to force the legs to lie straight in order to measure them, for they break off under very little strain. It would be better in this case to measure each joint individually and add them together for the length of the hindleg. The students would thus be getting the femur measurement at the same time. In the interest of time, if this Investigation is to be conducted by the entire class, it is suggested that the class be divided into several groups, with each group measuring a number of the grasshoppers, beans, and peas. Their results could then be tabulated for the entire class.

Student observations—answers to questions.

- (a) They approach a normal curve.
- (b) Answers will vary.

Interpretation. Two major causes of variations among members of a group are genetic differences and environmental factors. Genetic variations that are beneficial to the organism are retained by natural selection and passed on to offspring.

Chapter 14

The Diversity of Life

Until the work of Linnaeus, scientific communication was often difficult because complete and complex descriptions were necessary before biologists could be certain that they were discussing the same organism. In the biologist's efforts to learn about the large number of diverse organisms, he looks for similarities. Organisms that are similar are then placed in a common group.

Emphasis in this chapter should not be on naming and classifying specific organisms, but on seeking common characteristics among the great variety of living forms. The theories of evolution as they attempt to explain the diversity will then be more easily understood.

You may wish to develop an understanding of the need for a classification system by listing a number of well-known animals and asking the class for suggestions as to how they might be studied. Organisms could, for example, be grouped according

to their habitats, shapes, sizes, colors, or their possession of fins, wings, or tails. Thus, we could place grasshoppers, bees, birds, and bats all in one logical group of flying animals. At this time a question should be considered, however. What is to be the purpose of our classification? How can a system of grouping be efficient when such a large number of individuals are concerned?

Scientists have been seeking the answers to these questions for many years as they have searched for a natural system of classification. The fact that classification is artificial and not always concise usually disturbs students who expect science to be clear-cut and definite. Therefore, it is essential that they understand that even at the kingdom level there is not agreement among various biologists.

The students should be aware that our increase in knowledge of life has given new meaning to classification. No system is

completely satisfactory, as there is a gradation between types of organisms. The basis of grouping that was once structural similarity has been extended to include cellular organization, biochemical similarity, and genetic makeup. Attempts to explain causes for variations among the characteristics of similar organisms form the basis for the various evolutionary theories.

The need for a system of classification based on obvious relationships, similarities, and the intended use may be presented by listing a number of objects. For example, the students may be asked to catalogue marbles, water, wood, plants, chipmunks, milk, gold rings, air, peanuts, oxygen, and lime. Undoubtedly a variety of groupings will be made and each may be correct in its logic. The following characteristics probably will have been considered: solid, liquid, gas; living, nonliving; organic, inorganic; plant, animal, nonliving. Such an exercise will promote a discussion of many of the principles involved in the problem of cataloguing life.

P. 199: Cite examples of Latin names for several plants or animals students may be familiar with, and also have pupils look up scientific names for several common organisms in their own locality. Show the derivations of several of these names. A dictionary of biological terms and their Latin and Greek derivations is useful. Latin students may also be of help.

P. 203: Use the table at the bottom of page 203 and discuss why man belongs to a certain kingdom, phylum, class, order, family, genus, species.

P. 205, left column: Modern man is called *Homo sapiens*. Others such as *Homo neanderthalensis* were similar but are no longer extant. Refer to page 183, the geological time table.

P. 206, right column: Use the properties of viruses as an introduction to the next unit and refer to page 214.

Suggested Films

Classifying Plants and Animals (b&w&col, 11 min) Cor
Nature of Diversity (col, 28 min) AIBS McGraw-Hill
Order in Diversity (col, 28 min) AIBS McGraw-Hill

MAJOR CONCEPTS

1. From the time of Linnaeus until recently, most scientific classification has been based on structural similarity.
2. Biologists recently have considered characteristics such as cellular organization and biochemical similarity in classifying organisms.
3. The most conclusive evidence of relationship between organisms is their genetic makeup.
4. Taxonomic classification involves an artificial system of grouping organisms for our own convenience.
5. A species is structurally different from all other organisms; members can interbreed and produce fertile offspring; members have come from common ancestors.

ANSWERS TO QUESTIONS FOR REVIEW (Page 208)

1. Taxonomy.
2. Aristotle attempted to classify plants on the basis of structure and animals on the basis of their habitat.
3. Latin is ideal for scientific classification because it is unchanging, descriptive, and a root of many modern languages.
4. A scientific name consists of two parts. The genus name is first, and is a capitalized noun. The species name is, usually, an adjective. In some names, a third word indicates a variety.
5. Many names are used for the same organism, or one name is applied to many organisms. Common names are misleading, as "crayfish" and "starfish," which are not fish. They are, too often, based on environment, habits, and other characteristics that show no true structural relationship.
6. Scientific classification is based on structural and biochemical similarity, cellular organization, and genetic makeup.
7. Kingdom, phylum, class, order, family, genus, species, and variety.
8. In the past biologists grouped organisms into one of two kingdoms: Ani-

malia or Plantae. However, recently a great amount of research has focused on simpler forms of life. They are now considered to be neither plants nor animals.

9. Biologists usually agree on the following three general characteristics of species: a. A species is structurally different from all other organisms except for sexual differences (male and female), and slight variations resulting from environmental influences; b. members of a species can interbreed and produce offspring that are capable of further reproduction. In other words, all members of a species have the same genetic make-up; c. members of a species have come from common ancestors and will continue their species characteristics in offspring.

ANSWERS TO APPLYING PRINCIPLES AND CONCEPTS (Page 208)

1. The mouse and wren are about the same size, yet they are not related. Nor are the fish and crayfish, which share the same environment, nor the rabbit and grasshopper, which have a similar diet.
2. Answers will vary.
3. A species is a plant or animal sufficiently different from all others to justify a specific name. A breed or variety is only slightly different, but not enough to justify a new species name.
4. Any large unorganized groups of objects or body of facts can be simplified by using the principles of scientific classification.

Guide to Laboratory Investigations for Chapter 14

INVESTIGATION 14-1

A Study of Classification

Scope of the Investigation This Investigation is designed to familiarize the student with the use of a classification key as a means of identifying organisms. The student will find the use of keys an essential part of their biological studies, and several Investigations in subsequent units are dependent on the student's ability to use taxonomic keys.

Approximate time required The average student should be able to complete this entire Investigation within a period of 40-50 minutes.

A Part 1 Using a Classification Key

Suggestions for procedure. A mistake quite often made by students when using a classification key is that they attempt to use the key before they are completely familiar with the characteristics used in identification. For example, a student could waste a great deal of time and come up with many wrong answers in using this fish key if he were uncertain of the names of the various fins. Therefore, the student should take time first of all to familiarize himself with the terms referring to the structure of fish. Then he should consider each of the two possibilities listed under number 1, and upon making his selection, proceed to number 2 or 12, where he again determines which of the two statements refers to the fish he is attempting to identify. The student can compare the use of a key with solving a mystery or going on a treasure hunt, where each bit of information leads to another place where another piece of information leads to somewhere else, and thus each step leads him closer to the answer. He should also realize that one wrong choice somewhere along the way can cause him to take a wrong turn and end up in the wrong place with the wrong answer.

Student observations—answers to questions.

1. Atlantic salmon.
2. Bullhead catfish.
3. Rock bass (Redeye).
4. Carp.
5. Small-mouth black bass.
6. Eel.
7. Bluegill.
8. Brook trout.
9. Yellow perch.
10. White crappie.
11. Channel catfish.
12. Northern pike.
13. Large-mouth black bass.
14. Rainbow trout.
15. White sucker.
16. Wall-eyed pike.
17. Blue catfish.
18. Pickerel.

Suggested References for the Teacher—Unit II**Books**

- Adler, Irving. *How Life Began*. John C. Day Co., New York, 1958
- Auerback, Charlotte. *Genetics in the Atomic Age*. Oxford University Press, Fair Lawn, N.Y., 1956
- Beaty, John Y. *Luther Burbank, Plant Wizard*. Julian Messner, New York, 1943
- Clark, Sir W. E. L. *History of the Primates*. University of Chicago Press, Chicago, 1957
- Coon, C. S. *The Origin of Races*. Alfred A. Knopf, New York, 1962
- Coon, C. S. *The Story of Man*, 2nd ed. Alfred A. Knopf, 1962
- Dart, R. A. *Adventures with the Missing Link*. Harper and Row, New York, 1959
- Darwin, C. *The Origin of Species*. New American Library of World Literature, New York, 1958
- Darwin, C. *The Voyage of the Beagle*. Doubleday & Co., Inc., 1962
- Dobzhansky, T. *Evolution, Genetics, and Man*. John Wiley & Sons, Inc., New York, 1955
- Eiseley, L. *Darwin's Century*. Doubleday & Co., New York, 1958
- Fenton, Carroll L. *The Fossil Book: A Record of Prehistoric Life*. Doubleday and Co., New York, 1958
- Fisher, Sir R. A. *The Genetical Theory of Natural Selection*, 2nd rev. ed. Dover Publications, Inc., New York, 1959
- Grant, V. *The Origin of Adaptations*. Columbia University Press, New York, 1963
- Hill, J. and Hill, H. *Genetics and Human Heredity*. McGraw-Hill Book Co., New York, 1955
- Huxley, Sir J., Hardy, A. C. and Ford, E. B. *Evolution as a Process*, 2nd ed. George Allan & Unwin, Ltd., London, 1958
- Hulse, F. S. *The Human Species*. Random House, New York, 1963
- Jacques, H. E. *Living Things and How to Know Them*. Wm. C. Brown Co., Dubuque, Iowa, 1946
- La Barre, W. *The Human Animal*. University of Chicago Press, Chicago, 1954
- Levine, R. P. *Genetics*. Holt, Rinehart & Winston, New York, 1962
- Malthus, T., Huxley, J. and Osborn, F. *On Population: Three Essays*. New American Library of World Literature, New York, 1960
- Mayr, E. *Animal Species and Evolution*. Harvard University Press, Cambridge, Mass., 1963
- Mendel, Gregor. *Experiments in Plant Hybridization*. Harvard University Press, Cambridge, Mass., 1941
- Mettler, L. *Population Genetics and Evolution*. Prentice-Hall, Englewood Cliffs, N.J., 1964
- Moore, J. A. *Heredity and Development*. Oxford University Press, New York, 1963
- Muller, H. J. *Studies in Genetics*. Indiana University Press, Bloomington, Ind., 1962
- Peters, J. A. *Classic Papers in Genetics*. Prentice-Hall, Englewood Cliffs, N.J., 1959
- Sauer, C. O. *Land and Life; a Selection from [His] Writings*, ed. John Leighly, University of California Press, Berkeley, 1963
- Simpson, G. G. *Life of the Past*. Yale University Press, New Haven, Conn., 1953
- Sinnott, E. W., L. C. Dunn, and T.

Dobzhansky. *Principles of Genetics*, 5th ed. McGraw-Hill Book Co., New York, 1958

Smith, J. M. *The Theory of Evolution*. Penguin Books, Baltimore, 1958

Sootin, Harry. *Gregor Mendel: Father of the Science of Genetics*. Vanguard Press, New York, 1958

Stern, C. *Principles of Human Genetics*, 2nd ed. W. H. Freeman & Co., San Francisco, 1960

Strauss, B. S. *An Outline of Chemical Genetics*. W. B. Saunders Co., Philadelphia, 1960

Strickberger, M. W. *Experiments in Genetics with Drosophila*. John Wiley & Sons, New York, 1962

Tax, S. (ed.) *Evolution after Darwin*, 3 vols. University of Chicago Press, Chicago, 1960

Washburn, S. L. (ed.). *Social Life of Early Man*. Aldine Pub. Co., Chicago, 1961

Articles

Bearn, A. G., and German III, James L.

"Chromosomes and Disease." *Scientific American*, November, 1961

Beerman, Wolfgang, and Clever, Ulrich. "Chromosome Puffs." *Scientific American*, April, 1964

Crick, F. H. "The Genetic Code." *Scientific American*, October, 1962

Doumani, George A., and Long, William E. "The Ancient Life of the Antarctic." *Scientific American*, September, 1962

Ericson, D. B., and Wollin, G. "Micro-paleontology." *Scientific American*, July, 1962

Glaessner, Martin F. "Pre-Cambrian Animals." *Scientific American*.

Life Nature Library by the editors of LIFE, TIME, INC., *Evolution*, New York, N.Y., 1964

MacNeish, Richard S. "The Origins of New World Civilization." *Scientific American*, November, 1964

Newell, N. D. "Crises in the History of Life." *Scientific American*, February, 1963

Nirenberg, Marshall W. "The Genetic Code—II." *Scientific American*.

UNIT THREE MICROBIOLOGY

This unit stresses the organisms, as we now know them, are not easily placed into an animal or plant group. It is suggested, therefore, that a discussion on the artificiality of our taxonomic systems should lead toward an understanding of the reasons for placing some organisms in a kingdom Protista. The fact that biologists are not in complete agreement regarding taxonomy should not detract from the understanding of reasons for classification.

Many parasitic protists produce illness in their host organisms. A knowledge of the life history of disease-producing viruses, bacteria, protozoans, and fungi, is therefore important in their control.

Since many organisms in this unit are microscopic, a knowledge of the various tools by which the scientist learns about them will provide a valuable background. Not only the electron and compound microscope, but clinical and ultra-centrifuges, tracer elements, radiation, variations in culture media, laboratory animals, and many other tools serve the biologist. The use of these tools and the interpretation of the significance of the data obtained require that a biologist have a good understanding of chemistry, physics, and mathematics. The teacher may wish to pursue the discussion on the relationships of biology to other sciences.

This unit terminates with the algae, which are called simple plants by some biologists and protists by others. Regardless of their placement in taxonomy, the algae possess chlorophyll, and sometimes other pigments and are, therefore, autotrophic. This characteristic relates them to the green plants discussed in the following unit.

OUTCOMES

The study of this unit should result in:

1. Knowledge of the composition and structure of viruses.
2. Understanding the relationship between a virus and a living cell.
3. Appreciation of the contributions made by scientists of past years to our knowledge of pathogenic organisms and their control.
4. Familiarity with methods used in investigating the microorganisms.
5. Understanding of the relationship between the body and infectious organisms causing disease.
6. Knowledge of the roles of immune therapy, chemotherapy, and antibiotic therapy in preventing and treating infectious diseases.
7. Knowledge of the various ways in which infectious organisms spread from one person to another.
8. Acquaintance with bacteria and fungi as harmful, harmless, or beneficial organisms.
9. Familiarity with various forms of bacteria, their relation to environmental conditions, and their methods of reproduction.
10. Introductory understanding of methods by which bacteria are studied in the laboratory.
11. Understanding of the body defenses and principles of immunity to disease.
12. Understanding of public health measures in the prevention of disease and the role of the average person in helping to carry out community disease control.
13. Familiarity with protozoans as life in a primitive form.
14. Acquaintance with the high degree of specialization of cell structures in protozoans.
15. Realization that many protozoans are free-living, but many also cause disease.
16. Understanding the diversity of forms and methods of reproduction as illustrated in algae and fungi.
17. Appreciation of the role of algae in societies of aquatic plants and animals.
18. Acquaintance with mushrooms, molds, yeasts, and other fungi.

Chapter 15

The Viruses

The concept of the virus as being organized on a subcellular or molecular level should be made clear to the students. It is therefore suggested that the teacher review cellular structure and then describe the contents of a virus particle. The fact that the virus does not reproduce outside a living cell is a characteristic distinguishing it from living forms with which the students are already familiar.

The organization and composition of a virus will offer clues as to how a virus affects a cell and how immunity may be developed. Although the body's reaction to foreign protein is discussed in a later chapter, it may be introduced at this point by the teacher.

The fact that the virulence of a virus can be altered has been important in our

development of the polio vaccine. Some research today indicates a possible link between cancer and viruses.

In scientific discovery the importance of proper tools with which to work is again illustrated. Since the Frenchman Borel in 1903 claimed that cancer in lower animals and man may be virus-caused, new tools have been developed. The electron microscope has made possible the visual detection of viral particles. Pelletizing is used to concentrate into pellets centrifuged viral particles and cells. These pellets can be sliced into sections 10 millionths of an inch thick for examination under the electron microscope.

The development of better techniques for tissue culture has helped in the culture of viral material. Human leukemia cells can

be grown in quantity by using normal cells that have been subjected to heavy X-ray dosage. The rays stop the growth of the cells and make their nutrients available to the virus. Stillborn human embryos are another culture medium.

The teacher may wish to review here units of measurement used with these small particles and show how mathematics is used in research to statistically evaluate results, make graphs, and compute size.

P. 214, right column: Viruses, once they infect an organism, sometimes seem to disappear. This has led to the controversy over whether they are a cause of human cancers. Scientists can show their presence by utilizing cell filtrates to transfer the cancer to new animals, but rarely recover the virus. One explanation offered for this is that the cancer virus enters the cell and alters it so the cell can multiply indefinitely along with the virus. The free virus that can infect new victims only appears once in a while.

P. 219, left column: Use a bulb catalogue or, if possible, a fresh specimen to illustrate a "broken" tulip.

P. 220, left column: Effective vaccines are available for several virus-caused animal cancers.

Suggested Films

Between the Living and the Non-Living (b&w, 29 min) Ind

The Very Small (col, 28 min) AIBS McGraw-Hill

Thread of Life (b&w, 29 min) Ind

Viral Genes (b&w, 29 min) Ind

Viruses (col, 28 min) AIBS McGraw-Hill

MAJOR CONCEPTS

1. Although some viruses cause disease, many are apparently harmless.
2. Viruses are called noncellular (or subcellular) and are smaller than the smallest cells but larger than molecules.
3. Viruses are considered to be between the living and the nonliving. They contain DNA or RNA, but cannot reproduce outside a living cell.
4. Cells carry on metabolic activities continuously; an isolated virus does not.
5. The virulence of a virus may depend

on the environment in which it is growing.

6. Phage DNA within a bacterial cell functions as a gene and apparently substitutes its control for the action of bacterial genes.

7. Phage DNA alters the chemical machinery of the bacterial cell, causing it to synthesize phage particles.

8. Lysogenic phages may remain in a bacterial group for many generations before producing a lytic cycle.

9. Similar mosaic virus infections occur in the tobacco, tomato, potato, bean, cucumber, and tulip.

10. A virus infection generally results in the disrupting of metabolic processes of the cells involved and damage or destruction of the tissue.

ANSWERS TO QUESTIONS FOR REVIEW (Page 220)

1. The name *filterable virus* refers to the fact that it passes through the extremely small pores of unglazed porcelain filters used in separating bacteria from fluids.
2. Some are in the form of slender, needlelike rods, while others are spherical or cubical or brick-shaped. Still others have an oval or many-sided head and a slender tail somewhat resembling a tadpole.
3. Diseased tobacco leaves.
4. The shell of a virus is composed of elongated protein fibers. The core of a virus is composed of nucleic acid.
5. *Virulence* means potency.
6. Bacterial viruses, plant viruses, and human and animal viruses.
7. They conducted the first investigations of phage viruses.
8. A phage attaches to a bacterium with its tail down. Tiny hooks cause the phage to adhere to the bacterium as an enzyme dissolves the bacterial wall. Once the opening is made, the tail contracts, and DNA of the phage is injected into the bacterial cell. The empty protein phage shell remains outside. The phage DNA approaches the bacterial DNA and takes control of the chemical machinery of the bacte-

- rium, causing it to produce phage DNA and protein molecules. The bacterium soon contains 100 or more phage particles, which are released when the bacterial cell disintegrates. The cycle is then repeated.
 9. It is very difficult to introduce a phage at the site of infection. In some diseases, infection is widespread and it would be difficult for a phage to contact a sufficient number of bacteria to be effective. Human tissue environment may not be suitable for phage action.
 10. Tobacco, tomato, potato, bean, and cucumber leaf mosaics; potato leaf roll; curly top beet; peach rosette; aster yellows.
 11. A "broken" tulip is infected with a mosaic virus.
 12. Lysogenic phages are potential "seeds of destruction" because they can invade bacterial cells without causing immediate destruction.
 13. Smallpox, chickenpox, influenza, rabies, the common cold, and mumps.
- ANSWERS TO APPLYING PRINCIPLES AND CONCEPTS (Page 221)
1. The structure and virulence of a virus appears to be altered by the chemical nature and activity of the cell that produces it. The rabies virus, for example, becomes more virulent when grown in the brain and spinal cord of dogs. When the virus is grown in rabbits, it becomes less virulent for man and dogs but increases in virulence for rabbits. Mutations also may alter the virulence of a virus.
 2. Free phages cannot reproduce. A phage is a nucleoprotein consisting of a shell surrounding a DNA core. Bacterial genes control the synthesis of specific enzymes and other proteins characteristic of the particular organism. Phage DNA apparently functions as a gene within the bacterial cell, and alters the chemical machinery of the bacterial cell, causing it to synthesize phage particles.
 3. In active reproduction of a cellular organism, the cell divides and forms two by an orderly progression of events within the cell. A virus does not reproduce but causes another cell to reorganize in a way that it produces more viruses.
 4. Viruses are composed of protein and DNA, which are complex substances but very precise in composition. The complex structure imposes limits on their actions.
 5. The lysogenic phage may attach to a bacterial chromosome and thus become a foreign gene replicated by the bacterial cell during fission. It may then become active at a later time, when conditions are favorable.
 6. Some forms of cancer, such as a form of leukemia in mice, may be produced by injecting a virus-containing extract. More than 20 different kinds of malignant tumors have similarly been produced in laboratory animals. Since cancer is abnormal cell growth and growth is controlled by DNA, and since viruses alter the action of the DNA molecule, it seems logical to suspect the virus as a possible cause of cancer.

Guide to Laboratory Investigations for Chapter 15

INVESTIGATION 15-1

Composition and Lytic Cycle of a Bacterial Virus

Scope of the Investigation Opportunities for student investigation of viruses are necessarily limited in the high school course. However, the subcellular nature and composition of viruses and the effect of virus DNA or RNA on living cells are important understandings the student needs to develop. The diagram of a virus particle the student is asked to label will clarify the discussion of the composition of

a virus on p. 214 of the text. The student diagram of a lytic cycle of a phage virus provides a graphic illustration of the text discussion on pp. 216-218. This diagram also provides an understanding for the demonstration of destruction of cells of *Escherichia coli* in Part 3.

Approximate time required Parts 1 and 2 should be completed in 30-45 minutes. Because of incubation periods involved, Part 3 will require 3-5 days.

A Part 1 Structure and Composition of a Phage Virus

Suggestions for procedure. In addition to labeling the diagram of a phage virus in Fig. 15-1-a, the student should examine charts, diagrams, and photomicrographs of various virus particles. These are the only methods of familiarizing the student with the structure and composition of viruses. Stress the fact that a virus, while similar to a cell in containing a nucleic acid, lacks cytoplasm, plasma membrane, cell wall, and other cell organelles and is, therefore, subcellular.

A Part 2 Lytic Cycle of a Phage Virus

Suggestions for procedure. Since the actual destruction of a bacterial cell by a phage virus cannot be observed in the high school laboratory, the student is given instruction for preparation of a series of diagrams to illustrate a cycle of lytic infection. Each stage to be shown is described in detail. If possible, preface the preparation of this diagram with an examination of photomicrographs, charts, and other illustrations of bacterial destruction by a phage virus. The disorganization of synthesis in a bacterial cell by the presence of phage DNA and the resulting organization of virus particles by cell processes is an important concept. This understanding is necessary to interpret the results of Part 3.

C Part 3 Effect of *T-even* Phages on *Escherichia Coli*-Strain B

Suggestions for procedure. The procedures involved in this Part are advanced and require precise technique. Therefore, it should be undertaken only by advanced students who are thoroughly familiar with aseptic techniques. The study is ideal for a special project or a class demonstration. The work should be done simultaneously with other Investigations or on extra-class time. Since the student is required to prepare culture media, work with bacteria cultures, use pipettes, and perform other bacteriological procedures, many teachers may wish to delay this Part until the student has completed the Investigations in various phases of bacteriology in Chapter 16.

The student should be cautioned that *Escherichia coli*, while normally found in the human intestine, is pathogenic in other parts of the body and must be regarded as an infectious organism. The *T-even* phage is not dangerous since it attacks only bacteria.

Prior to conducting the experiment, the student should have prepared sterile nutrient agar and nutrient broth. Methods for preparing culture media are given in Investigation 16-2. Pure cultures of *E. coli*-Strain B and the *T-even* phage are available at biological supply companies. The broth culture of *E. coli* is prepared in a 500-ml flask containing 250 ml of sterile nutrient broth. Caution the student not to contaminate the broth while inoculating it with *E. coli* from the stock culture. The four Petri dishes used must be oven sterilized and poured to a depth of $\frac{1}{4}$ in. with sterile nutrient agar prior to adding the *E. coli* and phage suspension.

Pipettes are used in several procedures. The sterile broth may be drawn into a 10-ml pipette (graduated in 1-ml intervals) by mouth in measuring the 9-ml portions for the phage dilution tubes. However, a bulb should be used for drawing the *E. coli* inoculum and phage suspension into pipettes. After adding the 0.01 ml of phage suspension and 1 ml of broth culture of *E. coli* to each poured agar plate, the two must

be diffused thoroughly with a bent glass rod. This will produce a thin surface film in which plaques will appear after incubation.

Analysis and conclusions. Evidence of destruction of *E. coli* cells by the *T-even* phage is the presence of clear areas, or plaques, in the film of the surface of the media. Each plaque represents a single phage virus that multiplied during the incubation period in increasing numbers of *E. coli* cells. A visible plaque represents the destruction of many millions of *E. coli* cells by a like number of phage particles. The fact that the phage multiplied in bacterial cells was demonstrated further when phage particles were transferred from a plaque to broth and infected additional *E. coli* cells on a newly prepared culture.

Chapter 16

Bacteria and Related Organisms

It may come as a surprise to many students to realize that many bacteria are harmless, many are beneficial, and some are even essential for our existence. When viruses and bacteria are compared as to size and structure, it will become apparent that the bacteria more closely resemble their image of a cell. The differences between cells and the bacterial organism will help the students to understand why some biologists call them protists.

Any actual culturing of bacteria by the teacher must be carefully done, and if the students are to handle any cultures, very close supervision is essential. They must understand that a culture method provides optimum conditions for many pathogenic as well as nonpathogenic forms. A concentrated growth of a pathogen, therefore, could become a dangerous source of infection if not handled properly. The transfer of bacteria from a culture to a microscope slide requires experience in the techniques of handling pathogenic bacteria. Unless a teacher has had special experience in microbiological techniques, it is not recommended that deviation from the laboratory manual and special projects culturing unknown bacteria be performed. There are many good films showing these techniques.

The teacher should be certain that the pupils are aware of the reproductive rate possible during favorable conditions. The concept of how this increase in number alters the environment is basic to understanding succession. Although succession is discussed in a later chapter, the teacher may want to mention it here.

Motile bacteria can be found in most hay infusions after four or five days. The teacher may want to use such a culture for a short demonstration.

P. 224: A Latin student could explain the singular and plural of words like *coccus*, *bacillus*, *spirillum*.

P. 225, Fig. 16-3: Define *electronmicrograph*. Review the size of the micron.

P. 226, right column: Bacteria live in varied environments. One unusual example which causes trouble is the species that lives in an airplane fuel system.

P. 228: Discussion of bacteria that oxidize nitrogen compounds should include a mention of legumes and their importance to man as a crop as well as a soil enricher. See p. 667.

P. 230, left column: Agar-agar is an important lab culture medium. It can be obtained in small quantity in a drug store. At one time it was used as a solidifying agent in the candy called Turkish Delight. In Japan it is still used to make candy and is called kanten. Gelatin candies today are made with animal proteins.

P. 232, left column: Here is a good opportunity to discuss what would happen if there were no death or no bacteria to decay.

P. 232, left column: Cite the uses of vinegar. Students are always surprised to learn that when they buy vinegar they are paying for 4 percent acetic acid and 96 percent water.

P. 232, right column: The quality of flax differs and the poorer quality is generally used in cigarette paper. This plant has

such historical significance that it is a good subject for a report.

P. 233, left column: Ask how the holes in Swiss cheese are made (two species of bacteria are used). A report could be made on how different cheeses are made and the importance of ageing.

P. 234, left column: Refer to page 240 on food poisoning.

P. 234, left column: Call attention to vacuum packed foods and the newer technique known as "freeze-dry." Sometimes the chemicals used to preserve foods are not harmless. Sulphur dioxide is used in dried fruits for bleaching.

P. 235: Discuss syphilis from the objective viewpoint of a disease caused by a microorganism.

Suggested Films

Bacteria (col, 28 min) AIBS McGraw-Hill

Bacteria (b&w&col, 19 min) EBF

Bacteria: Laboratory Study (b&w&col, 15 min) Ind

Simple Plants: Bacteria (b&w&col, 13½ min) Cor

MAJOR CONCEPTS

1. Bacteria are primitive cellular organisms.
2. Prior to the existence of green plants, bacteria may have utilized energy from iron, sulfur, and nitrogen compounds.
3. Bacteria are the most abundant form of life.
4. Since bacteria are considered to be neither plants nor animals, they are now placed by many biologists in the kingdom Protista.
5. Bacteria are classified according to their shape and method of growth.
6. The slime layer produced by bacteria may protect them from unfavorable environmental conditions and enable them to stick to the surface of a food supply.
7. Some bacteria are motile and are propelled by flagella or by a corkscrew motion of the cell.
8. Although many bacteria are parasitic and saprophytic heterotrophs, some are chemosynthetic autotrophs.
9. Some bacteria have been found to reproduce sexually.

10. Although some bacteria cause disease, many are beneficial and some are used in industry.

11. Rickettsiae are considered to be the smallest living organisms and cause disease when they are transmitted by insects, ticks, and mites.

12. Spirochetes are protists lying between bacteria and protozoans in complexity; many are pathogenic.

ANSWERS TO QUESTIONS FOR REVIEW (Pages 236-237)

1. In an extract of the juice containing alcohol, Pasteur found the number of yeast cells to be directly proportional to the amount of alcohol. In the sour juices, Pasteur found rod-shaped organisms and no yeast cells.
2. Although the bacteria have until recently been classified with the fungi, many biologists consider them to be neither plants nor animals, so have placed them in the kingdom Protista.
3. Spherical bacteria range from 0.5 to 1.5 microns in diameter. The rod-shaped forms average from 0.2 to 2 microns in width and from 0.5 to 10 microns in length. The average length of bacteria is approximately 1.5 microns.
4. Bacteria are classified according to their shapes. Spherical forms are cocci; rod-shaped forms are bacilli; spiral or bent rod-shaped forms are spirilla.
5. All bacterial cells are surrounded by a slime layer of varying thickness. Some bacteria have a thick slime layer referred to as a capsule.
6. Bacterial cells contain DNA in genes that are concentrated in chromosome bodies lying near the center of the cell.
7. Various bacillus and spirillum forms of bacteria are equipped with threadlike whips, or flagella, which propel the cell through water or other fluids. There may be a single flagellum or one on both ends of a bacterial cell. In some forms, flagella may surround the cell. They

- are cytoplasmic extensions that project through openings in the cell wall and are composed of strands of protein molecules resembling the microscopic fibers composing muscle.
8. Brownian movement is random molecular motion. True movement of bacteria is accomplished by flagella.
 9. Favorable growth of bacteria requires a suitable temperature, moisture, darkness, and source of food.
 10. Heterotrophic bacteria may be saprophytic or parasitic. Autotrophic bacteria are chemosynthetic and can utilize inorganic compounds as an energy source.
 11. Aerobic bacteria require free oxygen for respiration. Anaerobic bacteria do not require free oxygen, and many cannot grow in the presence of atmospheric oxygen.
 12. Alcohol, carbon dioxide, pyruvic acid, and lactic acid.
 13. Methane and water.
 14. Bacteria multiply by fission or cell division. A cell may grow to maturity and divide in only 20 minutes.
 15. Some bacilli form spores which are very resistant to conditions of heat and drying.
 16. Bacteria cause decay and release chemicals for re-use. Many combine atmospheric nitrogen into forms usable by plants. Bacteria are used for making vinegar, sauerkraut, tanning leather, retting flax, silage, tobacco, and cheese.
 17. In the dairy industry bacteria are used in making cheese, sour cream, buttermilk, and yogurt.
 18. By heating milk slowly to 140-150°F, holding it at this temperature for 30 minutes, and then cooling it quickly, about 90 percent of the bacteria are killed. Rapid cooling retards the growth of surviving organisms.
 19. Foods may be preserved by killing bacterial cells as in canning and pasteurization. The environment may be made unfavorable for bacterial growth by the addition of chemicals, salting, refrigeration, quick freezing, drying, and by radiation.
 20. Rickettsiae are transmitted to humans by insects and their relatives, including the human body louse, ticks, and mites.
 21. Rocky Mountain spotted fever, typhus, trench fever, and Q fever.
 22. Syphilis, yaws, European relapsing fever, Vincent's angina, and infectious jaundice.
- ANSWERS TO APPLYING PRINCIPLES AND CONCEPTS (Page 237)
1. Bacteria lack a nuclear membrane, but DNA is concentrated in chromatin bodies. These bodies divide when the cell divides, with resulting replication of DNA.
 2. An inoculated bacterial culture will show a very slow increase in number of organisms, then a rapid increase in numbers, and then a decline. The retarded rate is due to a decrease in nutrients and the accumulation of metabolic wastes.
 3. Many bacilli form spores when conditions for growth and cell division become unfavorable. A single cell, including the genetic material, is drawn into a spherical or oval mass, and a single or double protective membrane forms. These can survive extremely unfavorable conditions. Growth may then continue when favorable conditions re-occur. This method of overcoming detrimental environments insures the continuation of the organism as well as its spread to new environments which may be suitable for its existence.
 4. Studies on *E. coli* have shown that two cells unite and the cell contents of one cell flow through a cytoplasmic bridge to the other cell. The significance may be that in recombination certain combinations result in changes allowing the organism to survive in new environments or to exist in changing environments.
 5. Rickettsiae seem to be midway between the bacteria and the viruses. They are barely visible under the highest magnifications of the light microscope. They are cellular and reproduce by fission as do bacteria.

However, like viruses, they can only live in direct contact with a living cell.

6. The spirochetes seem to lie between the bacteria and the more specialized one-celled protists called protozoans. The cells of spirochetes are long and cylindrical, forming spirals or cork-

screws. As far as is known, they have no organized nucleus. Reproduction is by transverse fission. None form spores. The bacteria, however, are rod-shaped or cylindrical and some form spores. Some bacteria move by flagella, and *Treponema* appears to have flagella.

Guide to Laboratory Investigations for Chapter 16

INVESTIGATION 16-1

The Bacteria — Forms and Motility

Scope of the Investigation This Investigation is designed to further acquaint the student with the general forms of bacteria he studied on p. 224 of the text. He should observe capsules, spores, and the action of flagella (pp. 224-226), and should be able to form some conclusions regarding the occurrence and function of these structures.

Approximate time required The average student should be able to complete Part 1 within 15 to 20 minutes.

Part 2 should require a period of 50-60 minutes.

Part 3 will require about 15 minutes to prepare the infusion two or three days prior to the observation, and approximately 30-40 minutes to make the observation.

A Part 1 Structure of a Bacterial Cell

Suggestions for procedure. This Part is designed as a workbook review of basic bacterial structure, and requires no special materials. Students should label the drawings in Fig. 16-1-a as directed.

Student observations—answers to questions.

- (a) It enables the bacterial cell to adhere to the host tissues and protects it against the antibodies of the host.
- (b) It is a virulent organism.
- (c) Rod-shaped or bacillus forms.
- (d) They are formed as a reaction to unfavorable conditions.

A Part 2 Forms of Bacteria

Suggestions for procedure. Because the students are as yet unfamiliar with the sterile technique used in studying living bacteria, it is strongly suggested that prepared slides be used for this study. Slides are available that have all the major forms mounted together. Students should observe each of the various forms and draw them in the spaces provided.

Student observations—answers to questions.

- (a) Answers will vary with organisms.
- (b) Should be able to.
- (c) Answers will vary.
- (d) Student answers will vary and can only be a rough estimate.

A Part 3 Study of Motility in a Hanging-Drop Preparation

Suggestions for procedure. A bean infusion should be prepared as directed in the student manual, and allowed to incubate for two or three days. Students should begin at this point to practice sterile techniques. They should flame the loop to redness before transferring a drop of the infusion to the cover glass, and should flame it again after the transfer. A toothpick should be used to place a thin ring of petroleum jelly on the slide surrounding the concave area. The slide should be inverted (hollow side down) over the cover glass and the two pressed gently together so the petroleum jelly seals them. The slide should then be inverted in a quick, smooth action, using a twist of the wrist. Turning the slide too slowly will cause the drop to run to the edge and into the concavity. The slide should be examined under high power. Students should obtain best results with a darkened field. After making the observations, the slides should be placed in alcohol, and then washed thoroughly.

Student observations—answers to questions.

- (a) Probably bacillus.
- (b) Possibly.
- (c) Usually streptobacillus.
- (d) Yes.
- (e) True locomotion and Brownian movement.
- (f) Individually.
- (g) Flagella.
- (h) Probably not. Light may be seen reflecting from some if the field is dark.

INVESTIGATION 16-2

Laboratory Culture of Bacteria

Scope of the Investigation This Investigation is designed to familiarize the student with various biological techniques in media preparation and culturing methods. Students prepare media and conditions to meet the needs of bacteria for growth, as discussed on pp. 226-227 of the text. They collect bacteria from a variety of objects and places, thus observing the universal distribution of these organisms. Students should become aware of the necessity of using sterile techniques, and should develop the idea that the tiny bacterial cell is potentially dangerous if handled in the wrong manner.

Approximate time required Part 1 will require about two and one-half hours for washing and sterilizing Petri dishes, and about two hours to prepare and sterilize the media. These activities can be correlated with other laboratory duties, in that much of the time involves mere waiting for materials to heat or cool. Pouring plates should require approximately 15 minutes, depending on the number of plates used.

Part 2 should require approximately 50-60 minutes to inoculate and expose the plates. After incubating for 48-72 hours, 30-40 minutes are required for observing colony growth.

A Part 1 Preparation and Sterilization of Cultures

Suggestions for procedure. Dehydrated nutrient agar, a supply of culture tubes and Petri dishes, a hot plate, autoclave, and hot-air oven are required for this study, in addition to other standard laboratory equipment. The Petri dishes can be sterilized in the oven at 350°F for two hours. They should be thoroughly washed and dried before sterilization, lest they become cloudy. They should be left closed, and covered with

clean towels until ready for use. Students should be cautioned against opening the Petri dishes at any time. The nutrient agar should be liquified according to directions on the label. It should be heated to boiling, stirring constantly to avoid scorching and to be sure all agar is dissolved. Tubes may be filled from a sterile funnel and sterile clamped tube, or from an Erlenmeyer flask. The cotton plugs should be inserted firmly, and the tubes handled gently to avoid getting the agar near the mouth of the tubes or on the cotton plugs. Media for the plates should be retained in a plugged Erlenmeyer flask for sterilization. Note that the tubes should be sterilized upright in a wire basket. The media should be sterilized in an autoclave or pressure cooker at 15 pounds of pressure for 15 minutes. Note that all air should be released before sterilization can be effective. The teacher should supervise the sterilization carefully, constantly noting the pressure, and regulating it if necessary. After sterilization is completed, the pressure of the autoclave should reduce gradually to zero, and the contents allowed to cool slightly before handling. Students should handle hot agar very carefully, for it may tend to stick to the skin and cause a painful burn. The tubes should be allowed to gel in a slanting position, with the surface of the agar ranging from the bottom of the tube to within one inch of the cotton plug. Note that the plug should not touch the agar. Pouring the agar from the flask to the Petri dishes should be done in such a way as to minimize the entrance of any organisms into the medium. Note that the mouth of the flask should be passed through a flame before pouring, and the lids of the Petri dish raised only enough to allow the medium to enter. Under no conditions should the lids be inverted or left off the dishes for even a few seconds. The agar in the dishes should be allowed to gel with the dishes placed on a level surface.

A Part 2 Inoculation, Incubation, and Examination

Suggestions for procedure. Stock cultures of *Serratia marcescens* or *Sarcina lutea*, sterile slants and plates, inoculating needles or loops, Bunsen burners, glass-marking pencils, an incubator, and samples of milk and stagnant water are required for this Part. If no inoculating needles are available, they may be made by inserting a 2-3 inch piece of platinum or nichrome wire in a metal handle or heated glass rod. The needle should be sterilized before and after each transfer of a culture. This is the best time to instill in the students the habit of routine flaming. They should remember that they always flame a needle when they pick it up and again before they lay it down. If there is the slightest doubt as to whether the needle has been flamed, it should always be flamed again. The best method of sterilizing a needle is as follows: move the tip of the needle into the flame slowly. (Some bacteria that have a fatty sheath or capsule tend to spatter if heated too suddenly.) Gradually move the needle to the hottest part of the flame (above the blue cone) and heat it to redness the entire length of the wire. Allow the needle to cool slightly before touching it to the culture source to avoid spattering the media and killing the cells. In inoculating slants, the mouth of the tube should be first passed through the flame. Slants should be inoculated according to the instructions in the student manual. Note that a light touch should be used; often students tend to dig into the agar with their needles. Although *Serratia marcescens* and *Sarcina lutea* are essentially harmless forms, the student should assume at all times that he may be working with a dangerous organism, and should exercise the most extreme care. Even harmless organisms can be potentially dangerous when present in such unusual concentrations as in a laboratory culture. Streak plates should be inoculated as directed in the student manual, again taking care not to leave the dishes open any longer than absolutely necessary, and a light touch used to avoid penetrating the surface of the agar. Contact plates can be made as suggested, using a variety of objects if a fly is not readily available. The dishes for exposure plates should be left open and undisturbed for 10 minutes. The lids should be placed beside them, taking care *not* to turn them up and thus collect additional organisms. Coughing on open dishes will provide additional exposures. These should then be covered immediately—

not left open for 10 minutes. A control plate should be left unopened to check for contamination in pouring or ineffective sterilization. All plates should be labeled at the time the inoculations, contacts, or exposures were made. Plates and slants should be incubated at 35°-37°C for 48 to 72 hours. Some signs of growth may be visible after 24 hours. Inoculated plates should always be incubated in an inverted position to avoid condensation on the surface of the agar. Slants and plates should be examined carefully, noting the following: number, shape, size, and color of colonies, texture of colonies, type of margins of the colonies, height and depth of the growth. Surface and side-view drawings should be made in the outlines in Fig. 16-2-a. After working with bacteria, students should always wash their hands thoroughly, preferably with tincture of green soap. They should make a habit of clearing their working area of all but the essential materials, to avoid any unnecessary contamination. Hands and pencils should always be kept away from the face, especially the eyes and mouth.

INVESTIGATION 16-3

Distribution of Bacteria

Scope of the Investigation This investigation is designed to make the student aware of the presence of bacteria in nearly every conceivable environment, including on objects and in areas very familiar to the student. If the student pursues the C-level Part 3, he should determine the effects of weather conditions on the number of bacteria in the air.

Approximate time required Approximately 50-60 minutes are required to prepare the plates and make the contacts and exposures in Parts 1 and 2. After 48 hours of incubation, about 30-40 minutes will be necessary to observe and study the plates.

Part 3 is a long-range project requiring at least one hour per day for two to four weeks.

A Part 1 Collecting Bacteria from Various Objects

Suggestions for procedure. Standard bacteriological equipment, including a colony counter, will be required for this study. Sterile agar plates should be prepared as in Investigation 16-2, and allowed to gel. Note that one plate should be retained as a control. Suggestions as to objects that can be used for contact plates are listed in the student manual, or have the students suggest various objects for testing. Note that in making the contact the lid of the Petri dish is raised slowly and held directly over the plate to keep dust from falling onto the agar. Students should be warned to touch the object lightly to the agar, rather than pressing it deeply into the agar. Plates should be covered immediately, labeled, and incubated in an inverted position at 35-37°C for 48 hours.

Student observations—answers to questions.

- (a) Usually.
- (b) Students may have used a sterile object, or have failed to touch the agar.
- (c) Usually.
- (d) Generally molds.
- (e) Air-borne spores are often present.
- (f) Answers will vary.
- (g) Answers will vary.
- (h) Answers will vary.

A Part 2 Bacteria in the Air

Suggestions for procedure. Additional sterile agar plates are required for Part 2. Students may suggest places to make the exposures, or use some of the suggestions listed in the student manual. Exposures should be made for 15 minutes, with care being used not to collect additional organisms in the lid of the Petri dish. The plates should be labeled, inverted, and incubated at 35-37°C for 48 hours. Students should calculate the number of bacteria falling per square foot per minute according to the instructions in the student manual.

Student observations—answers to questions.

- (a) Answers will vary.
- (b) Answers will vary.
- (c) Answers will vary.
- (d) Circulation of the air, number of people present, sanitation methods used in the area.
- (e) Air currents, relative humidity, light, air temperature, amount of dust in the air.

C Part 3 Effect of Weather Conditions on the Bacterial Count of the Atmosphere

Suggestions for procedure. The student will need three sterile agar plates for each day he conducts his study. The student should determine three outdoor stations in his community where he can expose plates for 15 to 30 minutes daily. The stations should not be sheltered from the weather artificially. The student should determine the daily weather conditions through use of weather instruments or by consulting the local weather bureau. Information should include the amount of light, precipitation, air temperature, relative humidity, air pressure, and wind velocity. Plates should be incubated for 48 hours and the number of bacteria falling per square foot per minute calculated from the average of each of the three daily exposures.

Analysis and conclusions. The student should find that wind velocity is the major factor in increasing the count. Barometric pressure has no effect, for there is not that much change at sea level. Moisture increases the count, for water carries bacteria too.

INVESTIGATION 16-4

Staining Bacteria

Scope of the Investigation This Investigation is a very important phase in the student's bacteriology work. He learns to use both simple and differential staining methods. Proper technique in handling bacteria is extremely important at this point, and should be stressed at all times. All parts of this Investigation will require close supervision by the teacher, for the students are working with concentrated cultures of many millions of organisms, and even harmless forms can be dangerous at these concentrations. Students should assume at all times that they *may* be working with harmful organisms, and thus use the proper techniques.

Approximate time required Depending on the amount of experience and study in preparation for this Investigation, students may require two 50-60 minute periods to complete this study. They should work very carefully and under the constant supervision of the teacher, so it may take the inexperienced student longer to complete this exercise than it first appears from reading the Investigation.

A Part 1 Staining Bacteria

Suggestions for procedure. Cultures used for this study should include agar plates or slants, bean infusion or a nutrient broth culture of a flagellated bacterium, and a broth culture of a known spore-forming organism. Stains and reagents required are crystal violet, methylene blue, safranin, 5% sodium bicarbonate solution, Gram's iodine, 95% alcohol or acetone, carbol fuchsin, and 5% acetic acid. Students should be cautioned against getting any of these stains on their clothing.

Section 1 *Use of simple stains.* A thin film of bacteria should be placed on a cover glass as directed in the student manual. Some teachers prefer to make the smears on slides, as they are easier for the students to handle and do not break as easily. Note that the inoculating loop should be flamed thoroughly after it is used to place the bacteria on the slide. Students should never lay a loop down without making sure it has been flamed first. After allowing the film to air dry, the cells should be killed and fixed by passing the slide or cover glass through a flame two or three times. The smear should be stained two to three minutes with crystal violet or another simple stain. The type of organism used and the concentration of the stain will determine the exact time required. Students may have to make several attempts in order to get the proper staining reaction. The excess stain should be washed from the smear by holding it under gently flowing water, or agitating it gently in a large beaker of water. After the smear has dried it should be examined as directed in the student manual.

Section 2 *Gram's differential staining technique.* Ability to use the Gram stain properly is absolutely essential for any student who plans to do further work in bacteriology. It is one of the most basic and widely used differential stains. A smear should be made and fixed as in Section 1. After flooding the smear with crystal violet and a few drops of 5% sodium bicarbonate, the smear should stand for two to three minutes. If students do not have access to a clock or watch with a second hand, the teacher may call out the time or use an automatic timing device. The smear should then be rinsed, stained with Gram's iodine for one or two minutes, and rinsed again. Then 95% alcohol should be used to remove any remaining stain, rinsing with a dropping pipette for 30-60 seconds. The smear should then be counterstained with carbol fuchsin or safranin for 30-60 seconds before rinsing it in water, drying it, and examining it as directed in the student manual. It may be of interest to have several students use the same organism and compare their results.

Section 3 *Spore staining.* Smears of a known spore-former should be made as in Section 1, and flooded with carbol fuchsin. The flooded film should be warmed gently above a Bunsen burner until the stain steams, but does not boil. This should be continued for five minutes. The stain should not be allowed to dry. Decolorizing should be done with 5% acetic acid. The counterstain should be methylene blue, used for three to four minutes. The smear should then be rinsed, dried, and observed as directed in the student manual.

Student observations—answers to questions.

- (a) Answers will vary; violet or red.
- (b) Answers will vary; Gram + if the cells are violet, Gram — if they are red.
- (c) Yes, if pure cultures are used.
- (d) Answers will vary.
- (e) Usually.
- (f) Appearance will vary. Spores usually oval or spherical, and central in position.
- (g) Blue, with red spores.
- (h) Usually.
- (i) Rods.

INVESTIGATION 16-5

Dilution and Plating-Out Procedures

Scope of the Investigation The dilution and plating-out procedures outlined in this Investigation are among the most widely used techniques in bacteriology. The student will apply these techniques in the analysis of milk and water in Investigations to follow. These analyses require skill in the use of pipettes in making accurate dilutions, pouring inoculated culture plates, colony counting, and calculation of bacteria counts in a sample from the colony counts of one or more plates in a dilution series. Procedures in the Parts of this Investigation are intended to develop skill in all of these procedures.

Approximate time required The time necessary to learn proper use of pipettes will vary with students. Most students can accomplish this in 15-20 minutes. Preparation of the dilution series and pouring the Petri dishes in Part 2 will require approximately 30-40 minutes, assuming that all preparations and sterilizations are made previously. Part 3 must be delayed 48 hours for incubation of the cultures. The counting of colonies in each set of plates and calculation of the bacteria count in a sample will require 20-30 minutes, depending on the nature of the results.

A Part 1 Developing Skill in the Use of Pipettes

Suggestions for procedure. Since the preparation of a dilution series requires accurate quantitative measurement of liquids, it is very important that the student learn to use pipettes and calibrated dilution bottles. Each student should be provided with 11-ml and 1-ml pipettes and two dilution bottles, flasks, beakers, or other containers from which he can transfer water. Preliminary instructions should include examination of the pipettes and the 11-ml and 1-ml calibration marks. If milk dilution bottles (160 ml) are used, point out the 99-ml calibration line. The teacher should also explain the meniscus at the surface of a column of liquid and illustrate on the chalk board the point at which a column of liquid is measured (the base of the meniscus).

The student should practice first with the 11-ml pipette. The teacher may wish to demonstrate the angle at which the bottle and inserted pipette should be held as well as the manner in which a pipette should be held, with the forefinger free and in position to cover the mouth end. The student should learn to draw water into the pipette slowly, watching the column of liquid rise to a point above the calibration mark. The end of the pipette is then covered with the forefinger to hold the column of liquid. Slight release of pressure on the tip of the pipette will allow the water to drip from the tip of the pipette one drop at a time. Control of the pipette will require practice. As the level of liquid in the pipette is lowered to the calibration mark, the pipette and bottle should be vertical with the calibration at eye level. When the accurately measured quantity of water is released from the pipette some will remain in the tip. Explain to the student that the pipette is so calibrated that the measured quantity has been delivered with this amount remaining. Therefore, it should not be blown out.

After the students have learned to use an 11-ml pipette, they should practice with a 1-ml pipette. This pipette is more difficult to use since it fills and empties quickly. Before proceeding to Part 2, it is suggested that the teacher have each student demonstrate his technique in using both pipettes.

A Part 2 Plating Out a Water Sample

Suggestions for procedure. Before starting this Part, the teacher should emphasize the importance of sterile technique, since a sample from a stream, drainage ditch, shallow

well, or cistern might contain harmful bacteria. This caution applies not only to using pipettes but to handling incubated cultures in Section 3.

Because of the number of dilution bottles, pipettes, and Petri dishes required for each sample, the teacher will probably need to divide the class into 4-6 groups, each of which will plate out one sample. Students in each group may rotate in preparing a dilution in a series. A single sample may be divided between the groups, or several different water sources may be used. In either case, division into groups will provide an opportunity for interesting comparisons.

Each group will require sets of pipettes, previously oven-sterilized and stored in pipette cans, if possible. Prior to starting the dilution series, dilution bottles must have been filled and sterilized in the autoclave. Each bottle must contain exactly 99 ml of water. The seventh bottle is used to supply any water lost during sterilization. Petri dishes, previously oven-sterilized, should be marked with the sample number, dilution factor ($0-1/1,000,000$), and date of plating. Nutrient agar, previously prepared, bottled, and sterilized in the autoclave, is re-heated to boiling, then cooled to 45°C for pouring. Unless a constant temperature water bath (45°C) is available, it will be necessary to maintain the medium at a temperature above 45°C , then cool it to pouring temperature.

Before starting the dilution series, students should study Fig. 16-5-a carefully. This will acquaint them with the principle of dilution in obtaining a bacteria count. Instruct the students to use care in diffusing the 1 ml of inoculum in each Petri dish into the warm nutrient agar at the time of pouring. About 20 ml of agar will pour each Petri dish to a depth of about $\frac{1}{4}$ in. (5 mm). Allow the poured plates to gel and cool to room temperature before inverting and putting in the incubator.

Before making the colony counts in Section 3, the teacher should explain the theoretical counts in a dilution series shown in Fig. 16-5-b. Arrange the incubated plates in order of dilutions from the sample (0 dilution) to the $1/1,000,000$ dilution. Each dilution should reduce the colony count to one tenth of the previous dilution. Students should account for all plates in a series in Fig. 16-5-c. The sample plate and several of the lower dilutions may be TNTC. If possible, have the students determine the bacteria count in the original sample from a plate with 30-300 colonies and correlate this count with a colony count based on the next lower and next higher dilution. This will probably be an approximate rather than a close correlation.

Student observations—answers to questions.

- (a) Answers will vary. If the bacteria count is very low, it may be based on the sample (0 dilution) plate.
- (b) If the sample contained less than 300 bacteria per ml, a dilution series would not have been necessary.
- (c) Crowding of colonies may prevent growth of all organisms present, as well as presenting a counting problem.
- (d) The higher dilution, the greater number of organisms in the sample each colony represents. Thus, the possible error in transferring measured quantities in making dilutions is increased greatly.

INVESTIGATION 16-6

Bacteriological Analysis of Milk Products

Scope of the Investigation This Investigation provides opportunity for the student to use the dilution and plating-out techniques learned in Investigation 16-5 in a bacteriological analysis. The laboratory study correlates with the discussion of bacteria in the dairy industry, pp. 233-234 of the text. Milk products are ideal for analysis in a high school laboratory. They are readily available in many forms. Variations in

bacterial content of various milk products provide an excellent opportunity for student interpretation of results in terms of age, handling, processing, sanitation, and other factors that may be involved. The teacher should explain that most of the organisms the student will find in milk products are normally present and do not indicate a health hazard. Otherwise, the student may become alarmed at the number of bacteria, even in fresh Grade A milk.

Approximate time required Assuming that all materials necessary for plating-out milk products are prepared in advance, students should complete the dilutions and pour the Petri dishes for one sample in 20-30 minutes. Plate counting will require 10-15 minutes.

B Part 1 Determination of Bacterial Content of Various Milk Products

Suggestions for procedure. This Investigation is ideally suited to group activity in which each student participates in part of the work but is responsible for results obtained by the entire class. The class may be divided into six or more groups with each responsible for one milk product. If fewer milk products are used, two groups may be responsible for a single one. If this is done, bacteria counts obtained may be averaged. If six samples are used, each group in an average-sized class would be four or five students. It is advisable to select one student as chairman. He is responsible for watching the dilution process to avoid mixing of pipettes, dilution bottles, and Petri dishes. These errors may occur when several students are involved in a plating-out procedure. The chairman should also report the results for his sample. As each chairman reports the results of his group, each student should record them in the table provided.

The various milk products suggested should be obtained fresh from a dairy or a grocery. They should be placed in a refrigerator until used. Media should be prepared in advance, bottled, sterilized, and stored in the refrigerator. Before use, it must be heated to boiling to liquify, then cooled to 45°C for pouring. Likewise, 11-ml and 1-ml pipettes and Petri dishes must be oven-sterilized and cooled in advance. Other advance preparations include preparation of sterile dilution bottles containing 99 ml of water. While plate count agar is recommended, other media suitable for growing milk organisms may be substituted.

When the incubated plates are ready for examination (after 48 hours of incubation), they should be arranged in order of dilution. Each student should examine all sets of plates and compare the results of the various groups.

Interpretation. In comparing results of the various milk products used by the class, the student should refer to all possible reasons for increases in bacteria content. Refrigeration is an important factor. Even with excellent conditions in the dairy, counts may increase during delivery and during the period the milk is in a case in a grocery. Handling is another important factor. Each process involved, including separation, addition of chocolate, or making of ice cream adds to the possibility of introducing bacteria. In cultured buttermilk, known bacteria are added as "starters."

INVESTIGATION 16-7

Effect of Temperature on the Growth of Bacteria in Milk

Scope of the Investigation The two Parts of this Investigation demonstrate the effect of heat on a bacterial population in milk. In Part 1, heat up to 98°F (37°C) is shown to accelerate the metabolic activities of bacteria and, therefore, increase the rate of growth. By means of plate-count determinations at 24- and 48-hour intervals, the

student compares the rate of increase in the number of organisms in milk at refrigeration temperature (40-45°F), room temperature (approximately 70-75°F), and incubation temperature (95-98°F). Results of these determinations stress the importance of refrigeration in delaying souring and other changes caused by growth and activity of bacteria in milk.

The procedures in Part 2 demonstrate the effect of much higher temperatures on bacteria in milk. In this Part, the student determines the decrease in bacterial population in milk pasteurized by the holder and flash methods as well as by boiling. Both parts of the Investigation relate to the discussion of bacteria in the dairy industry on pp. 233-234 of the text. Part 1 also relates to conditions for growth of bacteria on p. 226 of the text.

Approximate time required Part 1 will require approximately 30 minutes the first day, 30-45 minutes the second, and 30-45 minutes the third. The holder method of pasteurization in Part 2 requires 30 minutes after the milk has reached pasteurization temperature and at least 15 minutes to prepare the dilutions and plates after the milk has cooled.

B Part 1 Effect of Temperature on the Rate of Bacterial Increase in Milk

Suggestions for procedure. This Part is best conducted as a class group investigation or as an individual project. The media and all other materials and apparatus required should be prepared prior to dilution series.

On the day of plating, a quart of fresh pasteurized milk is brought to the laboratory and stored in the refrigerator until used. As soon as the milk is opened, it should be divided into three sterile 8-oz bottles, leaving sufficient milk in the original container for plating out a dilution series. If screw-cap bottles are used, the caps should be loose to allow air to enter; otherwise, the bottles should be plugged with cotton. The bottles are marked 1, 2, and 3. Bottle 1 is placed in the refrigerator immediately; bottle 2 is placed in a cupboard of the room; bottle 3 is put in the incubator.

The remaining milk should be used immediately in preparing a dilution series, using the procedure outlined in Investigation 16-5. The teacher may wish to divide the class into two groups and prepare two dilution series and two sets of plates. The counts obtained after incubation can be averaged to arrive at the bacteria count per ml at the start of the Investigation. This count is entered for all three samples in the table provided.

A similar dilution series and set of plates is prepared for all three samples on the second day (24 hrs incubation) and the third day (48 hrs incubation). The appearance and odor of the milk in each bottle should be recorded at both of these intervals. Since three dilution series are prepared the second and third days, the teacher may wish to divide the class into three groups, each responsible for plating one sample. If duplicate plates are made, six groups would be involved.

Results may be shown in a bar graph or a line graph, using different colors for the three samples. Each graph will show the same starting bacteria count per ml.

Student observations—answers to questions.

- (a) None.
- (b) Some separation of the milk and a slight sour odor.
- (c) Coagulation and separation of the solids and a strong sour odor.
- (d) None, usually.
- (e) Coagulation and separation of the solids and a strong sour odor.
- (f) Coagulation and separation of solids and a sour odor and an odor of protein decomposition.

Interpretation. Increase in temperature to 95-98°F results in increase in the rate of metabolic activities in bacteria. This is evidenced by the rate of souring and spoilage of the milk as well as in the increase in bacteria population.

B Part 2 Effect of Pasteurization and Boiling on the Bacterial Content of Raw Milk

Suggestions for procedure. The milk used in this Part must be raw (unpasteurized). A dairy may supply a raw milk sample on special request, or it may be obtained from a dairy farm. The culture media and all other materials and apparatus involved should be prepared and sterilized prior to conducting this Part. The raw milk must be refrigerated until used.

The raw milk is divided into four 500-ml Erlenmeyer flasks or other glass containers. If the entire class conducts this Part, students may be divided into four groups, each responsible for one procedure. One sample is plated in a dilution series without heat treatment. The bacteria count in this sample provides the basis for determining the effect of the various heat treatments. All of the heat-treated samples are to be checked for both flavor and odor after the dilution and plating-out procedures are completed.

The holder method of pasteurization may present a problem because of time involved. However, flash pasteurization and boiling can be completed and dilution plates prepared within a single laboratory period.

Bacteria count reduction in both pasteurization methods will vary but is often about 10 percent. Boiling should destroy the majority of bacteria present but will not destroy spores, which will germinate and form colonies in the cultures. Milk pasteurized by the flash process often has a "heated" or "scorched" odor and flavor. Students will also detect these odors and flavors in boiled milk. Boiling also causes the milk to coagulate.

Interpretation. Pasteurization reduces the bacterial content in milk and, therefore, reduces the rate of souring and other chemical changes. Heat also destroys many pathogenic organisms which may be present in infected milk.

INVESTIGATION 16-8

Bacteriological Analysis of Water

Scope of the Investigation Bacteriological analysis of water is of extreme importance in protecting the health of a community. For this reason, the procedures in this Investigation are important not only from the standpoint of microbiology but of public health as well.

Sterile technique is very important in water analysis. Students will probably be dealing with contaminated water supplies in determining total counts and in coliform analysis. *Escherichia coli* may appear in nearly pure culture on eosine methylene blue agar or Endo agar in the coliform determination. Students should use caution in handling these cultures since *E. coli* is pathogenic in certain body regions and tissues.

The stream analysis suggested in Part 2 may be conducted as a class project or an individual project. This Investigation may provide interesting and valuable data relating to stream pollution.

Approximate time required Preparation of media for water analysis and other apparatus used will require 40-50 minutes if the work is divided among groups. Preparation of a dilution series and inoculation of lactose broth fermentation tubes in Section 2 of Part 1 will require approximately 30 minutes per sample. Examination of lactose broth fermentation tubes and streaking of positive broth onto eosine methylene

blue or Endo agar after 24 hrs incubation will require approximately 15 minutes. Forty-eight hour examination of lactose broth fermentation tubes, streaking of 48-hour positive lactose broth, examination and interpretation of growth on eosine methylene blue or Endo agar plates and counting of plates in a dilution series will require 40-50 minutes per sample. The time required for Part 2 will depend on the extent of the study.

B Part 1 Bacteriological Analysis of Water Supplies

Suggestions for procedure. For the preparation of media and cultures used in water analysis in Section 1, the class may be divided into groups. This division of responsibility will save considerable time. Dilution and plating out and coliform analysis in Section 2 is also suited to group activity with each group responsible for one water sample. One student in each group should serve as a chairman to oversee the entire dilution process and inoculation of the lactose broth fermentation tubes. The chairman should also report results for his group to the class. On this basis, four to six water samples may be used. Samples of water supplies should include both deep and shallow wells and cisterns. If possible, include one source known to be polluted with sewage to demonstrate positive *E. coli* results.

Petri dish inoculations from the dilution series are made with 1-ml portions of the sample and all dilutions to 1/1,000,000, or seven altogether. These plates are poured with nutrient agar and incubated 48 hrs before counting. The 1-ml pipette used to inoculate the first dish directly from the water sample may also be used to inoculate 1-ml portions into each of five lactose broth fermentation tubes. These tubes are examined after an incubation period of 24 hrs. At this time, broth from all tubes showing gas is streaked onto eosine methylene blue or Endo agar plates. Use a straight inoculating needle and a zig-zag streak. These plates are incubated 24 hrs, after which they are read as positive or negative, depending on the presence of colonies of *E. coli*, described in Section 2. Lactose broth fermentation tubes containing gas in 48 hrs but that were negative in 24 hrs should also be streaked on the differential media but will probably show negative growth.

The table included in this Investigation provides space for data from one sample. Students may duplicate this table to record data from other samples.

Interpretation. The determination of water as safe or unsafe for drinking depends, primarily, on the coliform determination. While the presence of gas in lactose broth fermentation tubes is only a presumptive test for *E. coli*, water producing such a result should be regarded as questionable. The presence of *E. coli* on a differential medium in the confirming test indicates sewage pollution. The total bacteria count will vary with the source of the water. In many samples, these organisms are harmless soil bacteria. However, treated city water or water from a deep well usually contains from 0 to less than 100 bacteria per ml.

C Part 2 Stream Analysis

Suggestions for procedure. This Part may be conducted as a class Investigation or an individual student project. A stream flowing through a city or town where sewage and other polluting materials may be introduced makes an interesting study. The stream should be sampled at at least six stations one-half mile or one mile apart. The first sample should be upstream from the congested area. Include both deep areas and shallow rapids in the sampling stations.

Plate counts and coliform analysis are conducted as in Part 1. Results should be summarized in a table and shown in a bar graph. The study may include closer investigation of sources of pollution indicated in the analysis.

Analysis and conclusions. Conclusions the student may draw from his investigation will depend on the results obtained. If sudden increases in total count and coliform organisms occur, he should attempt to locate the source. On the other hand, aeration of water in fast-flowing shallow rapids may result in a decrease in bacterial content of the water.

Chapter 17

Infectious Disease

Further importance of the manner in which bacteria alter their environment is seen in the diseases they produce. Class discussions on this chapter should emphasize the characteristics of bacterial-caused disease, the bacterial effects on a living cell, and the body's reaction to the foreign substance—the bacteria. The historical approach may be used to exemplify the significant concepts of bacterial disease.

Outside reading assignments and short reports may contribute to the understanding of man's control of the bacterial infections. These may include the work of Jenner, von Bering, Pasteur, or Koch.

P. 239, Fig. 17-1: Define *pathology* and *pathogenic* and stress the importance of a department of pathology in a hospital. Here highly specialized technicians sometimes examine excised tissues while the patient is still on the operating table. This may help the surgeon to determine how much tissue must be removed. Some hospitals require that all excised tissue be examined in order to keep down the number of unnecessary operations.

P. 242, right column: Tears are necessary to keep the eye surface from drying out, to act as an antiseptic, to protect the eye from foreign objects by washing them out, and to express emotion. Students can see the duct that drains tears into the nasal passages by using a mirror. In Fig. 17-3, the effect of the cilia is shown. Nasal sprays containing oil immobilize the cilia and prevent them from expelling foreign matter.

P. 243, left column: Destroying intestinal bacteria normally present allows other bacteria to multiply and upsets the digestive process so much that some people develop antibiotic diarrhea. In severe cases a patient may be given a culture of the necessary bacteria to restore the balance.

P. 244, left column: Public programs may be set up on a large scale for vaccination. Polio and smallpox are two diseases for which such programs have been set up. A smallpox certificate issued within three years is required of persons coming from abroad.

P. 245, right column: At one time many people were scarred with pock marks. One superstition connected with vaccination was the belief that cowpox vaccination would cause cows' heads to sprout out of the arms of the person vaccinated.

P. 249: Ehrlich's "magic bullet," salvarsan, was an arsenic compound that was alternated with bismuth and mercury to keep the body from building too much tolerance for the arsenic and thus decreasing its effect on the disease.

P. 252: Antibiotics can either be of great help or great harm. Allergic people have been known to die from penicillin. Also, people build up an immunity to the drug's effect by using it for viral-caused diseases like the common cold. When the drug could be of value, it no longer has any effect.

Suggested Films

Infectious Diseases and Man-Made Defenses (b&w&col, 11 min) Cor

Infectious Diseases and Natural Body Defenses (b&w&col, 11 min) Cor

Microorganisms: Beneficial Activities (b&w&col, 15 min) Ind

Microorganisms: Harmful Activities (b&w&col, 15 min) Ind

The Germ Theory of Disease (col, 28 min) AIBS McGraw-Hill

MAJOR CONCEPTS

1. Koch's postulates are a series of logical steps used to identify a disease-producing organism.
2. Infectious organisms may spread in many ways.
3. Microorganisms may damage the body mechanically or chemically.
4. Skin, membranes, tears, and the acid reaction of the stomach fluids are structural defenses against disease.
5. Specialized cells of the body engulf and destroy bacteria. Some of these cells move throughout the blood stream or tissue spaces while others are stationary.
6. Antibodies and antitoxins form a chemical defense of the body against disease.
7. Immunity against a disease may be natural or acquired.
8. Immune therapy involves either a vaccine or a serum while chemotherapy involves chemicals.
9. Living organisms and their products may also be used to combat disease.

ANSWERS TO QUESTIONS FOR REVIEW (Page 253)

1. Viruses, bacteria, rickettsiae, spirochetes, protozoans, molds and mold-like organisms, yeasts, and parasitic worms.
2. a. Isolate the probable organisms causing the disease (Koch found them in the blood stream of infected animals); b. grow the organisms in laboratory cultures (Koch used vitreous humor from ox eyes); c. inoculate a healthy animal with the cultured organisms (Koch inoculated mice); d. recover the causative organisms from the infected animals (Koch found the organisms had multiplied enormously in the blood stream of mice).
3. In food-borne infections, the food is the agent in which bacteria are introduced into the body. Food poisoning results from consuming pre-formed toxins produced in food by bacteria.
4. Colds, sinus infections, measles, scarlet fever, and tuberculosis.
5. Ringworm, impetigo, chickenpox, syphilis, and gonorrhea.
6. Typhoid fever.
7. Exotoxins are chemical substances which are produced by many bacteria and have damaging effects when absorbed by surrounding tissue or when transported through the blood stream. Endotoxins remain inside the bacterial cells that form them. These toxins are released with deadly effect when the bacteria die and disintegrate.
8. Skin, mucous membranes, mucus, tears, and acid of the stomach.
9. Lysozymes are enzymes that actually dissolve an infecting organism.
10. Leucocytes and cells lining the small blood vessels in the liver, spleen, lungs, and bone marrow.
11. Fever reduces or inhibits the growth of many bacteria.
12. An antigen is a foreign protein that stimulates the production of specific antibodies that combine with the antigenic material in the blood.
13. Natural immunity is acquired by having a disease and recovering from it. Artificial immunity is brought about by the injection of antibodies that have been formed by the blood of other individuals or from animals.
14. A toxin is a substance produced by some bacteria, such as the diphtheria bacteria, which acts as a poison to the body. Antitoxin is a chemical produced by the body which counteracts the toxin. It is found in the blood of animals that have recovered from the disease and has been used to produce temporary immunity. A toxin-antitoxin is a mixture of the two, and it has been used to produce immunity. However, some people have had serious reactions to injections of this mixture. Toxoid, which is toxin that has been weakened with heat and chemicals, has been used to produce immunity to diphtheria, as it is safer.
15. Paul Ehrlich succeeded in discovering a drug that killed the syphilis organisms in the blood stream

without damaging blood or the other parts of the body. It was an arsenic compound called salvarsan. Gerhard Domagk discovered the germ-killing powers of a red dye called prontosil. Later it was found to be one of the sulfa drugs.

16. Antibiotics are products of living organisms.

ANSWERS TO APPLYING PRINCIPLES AND CONCEPTS (Page 253)

1. Koch isolated the organisms causing anthrax and found that they could be transferred from a sick animal to a healthy animal and cause the disease in the healthy one. He was also able to culture the organisms in the laboratory and use them to infect healthy animals. Koch's procedure is summarized in Koch's postulates.
2. The specific body defenses are the antitoxins and antibodies, each of which combats a particular organism. The nonspecific body defenses include the skin, mucous membranes, tears, lysozymes, and phagocytes which are part of the first-line and second-line defense mechanisms and are effective against all microorganisms.
3. Edward Jenner began immune therapy when he successfully inoculated a boy with cowpox, thus making him immune to smallpox.
4. Emil von Behring studied diphtheria and was puzzled by the fact that the effects of the disease appeared in organs that were distant to the site of infection. He made cultures of the bacteria and studies of the toxin produced. He discovered the immune reaction that was produced when fractions of the blood from animals surviving injections of toxin were injected into other animals. He called this substance antitoxin.
5. Pasteur found that an injection of weakened bacteria would produce immunity against a disease. Although he didn't know about viruses, he found that rabies could be transmitted from infected brain tissue of a rabid dog to a healthy one. He found that if spinal cord tissue was taken from a dog or rabbit and dried for 14 days, the infective agent lost its strength and could no longer produce the infection. Virus 13 days old was only slightly stronger. The discovery that the virus weakened with drying and aging led to experiments to produce immunity by a series of injections with materials of increasing strength.
6. Any variant that allows a bacterium to survive antibiotic treatment would also occur in its offspring. While most bacteria are killed by the drug, the resistant strain may increase in number as its competitors are eliminated.

Guide to Laboratory Investigations for Chapter 17

INVESTIGATION 17-1

Effect of Antiseptics on the Growth of Bacteria

Scope of the Investigation In this Investigation the student actually observes the effect of antiseptics as he tests them against known bacteria. The results are graphic and provide evidence that some of the highly advertised antiseptics have little or no effect against bacteria.

The student should gain a better understanding of why some agents are classified as good disinfectants and formaldehyde a good preservative when he finds that they have cleared an inoculated Petri dish. From his observation of the ineffectiveness of alcohol against bacteria, the student should conclude that it is a good cleaning agent around cuts, but that it evaporates too quickly, making it ineffective against bacteria in the Petri dish.

In determining the lethal concentration of antiseptics on test organisms, the student is using one of the techniques employed by drug companies in testing the effectiveness of their antiseptics.

Approximate time required. The inoculation of the sterile broth with the test organisms will require 10 minutes. The inoculated broths require 24-hour incubation prior to use in Parts 1 and 2. The initial work of preparing the plates, allowing them to gel and putting the antiseptic disks on them requires 40 minutes. Time can be saved by having the agar cooled to 45°C and ready for pouring the plates following inoculation with the broth cultures. The inoculated Petri dishes with antiseptic disks are incubated for 48 hours. The examination and collection of data will require an additional 50-60 minutes. This Part may be correlated with Investigation 17-2.

It will require 15 minutes to transfer the various broth cultures to the sterile culture tubes in Part 2. An additional 20 minutes will be required for the introduction of the antiseptics to the broth cultures. Time may be saved by assigning this Part as a group project with teams of four or five students. The culture tubes will require 24 hours for incubation. Examination of the culture tubes, microscopic study of the broth, and streaking of the agar plates with the broth cultures after incubation will require 50-60 minutes. Again, time may be saved by having the same team that prepared the culture tubes with the broth cultures and antiseptics collect the data and streak the agar plates. The streaked agar plates require 48 hours for incubation. This Part requires careful planning since it actually requires a total of four days to complete.

B Part 1 The Inhibitory Effect of Various Antiseptics on Bacteria

Suggestions for procedure. Students should bring the antiseptics from home. Many of the common antiseptics and the 5% phenol solution may be purchased in two-ounce quantities from a drug store or pharmacy.

The student should use a sterile pipette equipped with a bulb to transfer the 1-ml quantity of inoculum to each of the Petri dishes. The same pipette may be used for each transfer of a given broth culture. Students should never draw up inoculum by mouth. When all of the plates have had the inoculum added, the student should pour the plates to a depth of approximately 6 mm, then gently rotate the plates so that the inoculum is well dispersed. Caution the student not to get agar on the cover.

The disks of filter paper may be punched out while the agar is gelling. Forceps need not be sterilized for use with the antiseptics. When the agar has gelled, saturate three disks of filter paper, one at a time, in the selected antiseptic. The disks should be held above the bottle and allowed to drain. Point out to the student that the antiseptic might drip on the plate or too much antiseptic will spread out on the plate, giving incorrect data. Caution the student to place the disks three-quarters of an inch from the rim of the plate and at 12 o'clock, 4 o'clock, and 8 o'clock. Point out that this is necessary because the student is interested in a zone of inhibition that is formed around the disk. The student should not invert the plates, since the disks may fall off the agar.

After the 48-hour incubation, the student should examine the plates for clear zones of inhibition around each of the disks. Then, using a metric ruler, he should measure these zones. To obtain a qualitative result, the student should measure the width of the zone on each side of the disk. Then make two additional measurements at right angles to the first. Determining the average for each of the three disks on the plate will give him a qualitative result of the effectiveness of the antiseptic against the bacterium. All data collected should be recorded in the table provided. If there is no zone present on the plate, record the result as zero. If the plate is clear, as is usually the case with the formaldehyde, mark the result in the table as clear.

The student should conclude that many of the more effective agents are damaging to body tissues when used in high concentrations. They should also conclude that advertising claims are not always reliable.

In comparing the zone averages of the various antiseptics with the zone around the 5% phenol solution, the student should conclude that the antiseptic is better than, equal to, or less effective than the 5% phenol.

Interpretation. Some of the antiseptics will be more effective against the gram-negative organisms than against the gram-positive ones. The strength of the antiseptic is an important factor to consider in relating effectiveness to the zone. Many of the antiseptics are designed to inhibit the growth or kill specific organisms. Technique in saturating the disks should also be considered in drawing conclusions concerning antiseptic effectiveness. The rate at which the antiseptic diffuses through the medium is another factor that could influence its effectiveness.

B Part 2 Determination of a Lethal Concentration of Antiseptics on Test Organisms

Suggestions for procedure. The student may use the antiseptics that were used in Part 1 of this Investigation. This Part should be done as a group project with teams of four or five students. Each group should be responsible for the transfer of broth to the series of culture tubes and for testing one antiseptic against the test organism.

The same sterile pipette is used for transferring the 20 ml of broth to each of the tubes in a series. A pipette with a bulb should be used, since a student should never draw up inoculum by mouth. Technique is extremely important in this Part. The student must make accurate measurements being sure to transfer exactly 20 ml of inoculum to each culture tube and to count exactly the number of drops of antiseptic introduced into the series of tubes. Point out that a control is necessary for comparative purposes of turbidity. The student should not use an antiseptic that is too dark for this study since it would be too difficult to check turbidity. All tubes are incubated following the introduction of the antiseptics for 24 hours.

After the incubation period, the tubes should be checked against the control for turbidity. The conclusions are based on a qualitative rather than a quantitative determination. The data relating to the turbidity should be recorded in the table provided. Point out that the turbidity is due to the presence of bacteria, but that a clear tube does not necessarily represent destruction of all the bacteria by the antiseptic. To determine whether any viable bacteria are present, the student should prepare a hanging drop of the culture and look for motility. The results of the examination should be recorded in the table provided. To further determine whether viable organisms are present, a streak plate of the broth cultures should be made and examined after 48 hours.

If there is a correlation between the broth turbidity, hanging-drop examination, and growth on the Petri dishes, the student can draw valid conclusions as to the number of drops of a particular antiseptic required to kill all the organisms in a broth culture.

Interpretation. The lethal concentration of 5% phenol against these two bacteria is usually 3-5 drops in 20 ml of heavily seeded broth cultures. Tincture of merthiolate 1:1,000 and mercurochrome 2% or tincture of iodine 2% should kill all organisms at a concentration of 5-7 drops. Ten drops of alcohol probably would not be lethal to the organisms. There will be a wide variation in the lethal concentration of other antiseptics.

The apparent absence of turbidity could show positive results in a hanging drop and on the streak plate because a few bacteria might not cloud the medium. However, these could be present and be picked up and transferred to the slide or agar plate in the inoculating loop.

It is also possible for the turbidity to be high, but negative results show up in the hanging drop or streak plate. Technique could be at fault or the bacteria did not adjust to the agar medium within the growing period.

INVESTIGATION 17-2

Effect of Antibiotics on Bacteria

Scope of the Investigation In this Investigation the student will observe the inhibitory activity of antibiotics as he uses antibiotic sensitivity disks to determine whether bacteria differ in sensitivity to antibiotics. His observation of the presence or absence of zones of inhibition around the disks should give him a better understanding of how antibiotics such as the ones he studied on pp. 250-252 of the text were tested to determine their effectiveness against bacteria.

The student actually demonstrates that some antibiotics are more effective when combined with other substances such as a metal. This study emphasizes the value of giving antibiotics in combination with other substances.

In attempting to find antibiotic substances in the soil, the student is repeating the type of investigation Waksman did when he found streptomycin (page 251 of the text). From this work the student should develop a concept of the importance of antibiotics in the microbiology of the soil.

Approximate time required Each Part will require 50-60 minutes for the initial work of making the plates and putting the various disks on them. However, the broth cultures must be prepared and incubated for 24 hours previous to the work. The nutrient agar will have to be liquefied and reduced to 45°C for pouring before the student can begin his work. The Petri dishes will have to be incubated for 48 hours after inoculation. The examination and collection of data will require an additional 50-60 minutes for each Part.

These Parts can be done on alternate days and run concurrently with Investigation 17-1.

B Part 1 The Inhibitory Effect of Antibiotics on Bacteria

Suggestions for procedure. This Part should be done by groups of students working as a team. The bacteria suggested for this study are relatively harmless and safe for high school students to handle. However, aseptic technique must be used and all bacteria treated as though they were harmful. Pure cultures of the bacteria may be purchased from biological supply houses. Substitutions may be made, but the study should include both gram-negative and gram-positive organisms. The Difco-sensitivity disks saturated with known quantities of antibiotics (usually referred to as low, medium, and high concentration) can also be purchased from biological supply houses or from Difco Laboratories. It is not necessary to sterilize the filter paper from which the disks are punched. However, the antibiotic should be prepared and stored under sterile conditions.

To save time, a student or students should be responsible for preparing the nutrient agar and broth and for sterilizing these and the Petri dishes and pipettes previous to the period when the experiment is done. Broth cultures will have to be inoculated with the various bacteria and incubated for 24 hours preceding the experiment.

Certain students should be assigned to labeling the Petri dishes with the proper name of the antibiotic and bacterium to be tested.

A pipette equipped with a bulb must be used to draw up the inoculum for preparing the Petri dishes. Students must never draw up bacterial inoculum by mouth.

Warn students to let the agar gel before putting disks on the plates. Plates are not to be inverted during incubation since the disks might fall off the plates.

Point out that the zones of inhibition provide qualitative rather than quantitative results. Discuss with the student the various variable factors and the fact that sensi-

tivity is determined by the presence of a zone, not by the size of the zone. From his study, the student should be lead into a discussion of specificity in bacteria. The student should conclude that not all the antibiotics are equally effective against each type of bacteria.

Student observations—answers to questions.

- (a) Only the cells in the most active state are killed by the antibiotic. As the antibiotic diffuses through the medium, the low concentration may actually result in the stimulation of growth.

Interpretation. Answers will vary. Penicillin should be effective against gram-positive organisms. Streptomycin will be more effective against gram-positive than against gram-negative organisms. The other antibiotics are classified as broad-spectrum antibiotics and should be equally effective against both gram-positive and gram-negative organisms.

B Part 2 Antibacterial Action of an Antibiotic and a Metal

Suggestions for procedure. This Part should be done by groups of students working as teams or by a student interested in doing additional work with antibiotics.

Point out that doctors often give antibiotics in combination with each other or with other substances such as a metal. They have found, for example, that *Escherichia coli* will respond to penicillin when given in combination with cobalt. This is an example of synergism.

The stock cultures of bacteria may be purchased from a biological supply house. It will be necessary to purchase the antibiotics on prescription. A family physician will often write a prescription for a student who is doing special work in the field of microbiology.

The metal chloride solutions should be prepared before the students are ready to do the experiment. The broth cultures and sterilization of glassware and the liquefaction of the agar must be done ahead of time.

This Part requires a large number of Petri dishes, and you may wish to reduce the number of bacteria to be tested with the metal chlorides. *Bacillus subtilis* and *Escherichia coli* should be the two bacteria used in the study.

The filter paper strips may be saturated with the antibiotic by putting them in a Petri dish containing the antibiotic. The forceps used to remove the saturated filter paper strips should be sterilized in alcohol.

The filter paper strips used for the metal chlorides may be dipped into the chloride solution and then held up to drain before placing them on the gelled agar. The student should make sure that the agar is gelled before placing the saturated antibiotic disk on the dish. Then the strip saturated in metallic salt should be placed over it at right angles, as shown in the student manual.

The plates should not be inverted, since the filter paper strips might fall off the agar.

When the students examine the plates and compare them with the control in which water was substituted for the metallic salt, they will readily observe that some antibiotics are more effective when certain metals are present. However, some antibiotics are rendered less effective by the presence of some metallic salts. A clear area in the angle formed by the two strips that is greater than the area on either side of the strips indicates that the presence of the metallic salt has increased the effectiveness of the antibiotic. If the area is less, then the metallic salt has acted as an inhibitor of the antibiotic action.

Student observations—answers to questions.

- (a) The control was used to demonstrate that it was the metal that increased the inhibitory action of the antibiotic.

Interpretation. Zones in the angles between the metallic salt and the antibiotic strips are larger than the zone of inhibition on either strip when the metallic salt increases the antibacterial effect. There may be no zone at all in the angle indicating inhibition. Or the zone in the angle may be the net combination of the zones produced by each of the inhibitors.

B Part 3 Searching for Antibiotics in the Soil

Suggestions for procedure. This Part should be done by a group of students working as a team or by a student who wishes to study more about antibiotics and to repeat the technique used for locating antibacterial agents in the soil.

Students should be assigned to sterilize the equipment used and to prepare the potato-dextrose agar. This must be liquefied and cooled to 45°C for use in this Part.

Soil samples may be obtained from a number of places, yards, woods, gardens, or fields. All samples should be collected in sterile collecting bottles. Students will use the dilution and plating-out technique they used in Investigation 16-3.

After the plates have been incubated, the student should examine the plate carefully for *Aspergillus* and *Penicillium* molds. The molds that are selected for use should be transferred to sterile potato-dextrose agar slants with a sterile inoculating needle. After incubation, make sure that the student has a pure culture of the mold that he has chosen for study. Potato-dextrose agar plates should be prepared and allowed to gel. Then have the student transfer a mold culture from the slant to the gelled plate. These plates should be incubated at room temperature for two days.

Using the technique illustrated in the student manual, the student should streak at right angles to the mold culture the various types of bacteria he has in stock. These may be the ones he used in Parts 1 and 2 of this Investigation. After inoculation, the plates should be incubated at room temperature for 72 hours. The student should look for any clear zones or areas of inhibition. If these are present, he has found an antibiotic substance that inhibits the particular bacteria he chose for his study.

Interpretation. Students may find that some antibiotic substances are present in the soil samples they tested. Not all of the bacteria tested will be inhibited. It is possible that the student will not find any antibiotic substance in the soil samples.

Chapter 18

The Protozoans

Although much laboratory work has preceded this chapter, the microscopic observations of stagnant water, pond water, and stream water seem to revive interest and enthusiasm. Every drop of water may contain a new world of organisms which have previously been seen only in a film. This first-hand experience will be long remembered by the students. Prepared cultures may be available for demonstrations or student use, but there is much satisfaction in finding a paramecium or euglena or ameba in a drop of water brought in by the student from ponds, flower vases, bird baths, or their own hay infusion.

Euglenas can often be found almost in

pure culture in quiet pools along streams and rivers. Watch for water with a bright green color. Hay infusions made about ten days in advance will also provide many ciliates. Water from flower vases is usually an available source of paramecia.

Protozoan diseases can be covered in special reports given before the class. Malaria is of special significance. Prepared slides of parasitic protozoans may be obtained from supply houses if a more extensive study is desired.

P. 254, right column: Ameboid movement is also typical of white corpuscles in humans.

P. 256, Fig. 18-2: Compare this with

Fig. 18-3 as suggested and give the functions of the parts shown. Students have difficulty realizing that these animals have three dimensions.

P. 260: A pure culture of euglena can be divided in two, and one half left in bright light and the other in darkness for comparison.

P. 262, Fig. 18-7: Compare the alighting position of the two species of mosquito. *Vector* is a new term for the students. A vector may be present without the disease being spread because the vector is not infected. This is true of the malaria mosquito in New Jersey. The diagram illustrates the process described in the answer to review question 9.

P. 263, right column: Bacterial dysentery may also be present in the tropics. In Mexico it goes by various names like the "trots" and the "Aztec Curse."

Suggested Films

Ameboid Organisms (col, 28 min) AIBS McGraw-Hill

Asexual Reproduction (b&w&col, 10 min) Ind

Life in a Drop of Water (b&w&col, 11 min) Cor

Protozoa (One-Celled Animals) (b&w&col, 11 min) EBF

Protozoa: Structures and Life Functions (b&w&col, 16 min) Cor

MAJOR CONCEPTS

1. The highly specialized organelles of the protozoans enable them to live efficiently as single cells, carrying on all the life processes.
2. Varying methods of locomotion conveniently divide the protozoans into four groups.
3. Soluble substances and water pass through the plasma membrane. Water-excreting mechanisms rid the protozoans of excess water that enters the cell with food and by osmosis.
4. The multitude of protozoan species illustrates the diversity occurring at the cellular level.
5. Methods of reproduction in various members of this group are fission, conjugation, and the formation of spores.

6. Some protozoans are a food source for small animals.
7. Some protozoans produce disease.
8. Protozoans help to digest food in the intestines of some animals.
9. The euglena has both plant and animal characteristics.

ANSWERS TO QUESTIONS FOR REVIEW (Page 264)

1. Sarcodina, Mastigophora, Sporozoa, and Ciliata. Protozoans are divided into phyla on the basis of their means of locomotion. Examples of the phyla, in the order named, include: ameba, euglena, *Plasmodium*, and paramecium.
2. The ameba extends pseudopodia around a food particle and engulfs the particle into a food vacuole.
3. The action of the cilia, which line the oral groove of the paramecium, and the movement of the animal groove of the paramecium, and the movement of the animal forward force food particles into the mouth cavity.
4. Paramecia multiply by fission and divide laterally. Rejuvenation is accomplished by the exchange of nuclear materials during conjugation.
5. Illustrations of sensitivity in the paramecium include the movement around objects by responding to touch, congregation around food, and explosion of the trichocysts when irritated by acid, ink, and other chemical substances.
6. Plant characteristics are: the presence of chlorophyll and chloroplasts, and photosynthetic activity. Animal characteristics are: flagellum, eyespot, gullet, reservoir, thin membrane, and euglenoid movement.
7. Flowing cytoplasm of the ameba, especially the inner endoplasm, flows against the flexible plasma membrane, causing it to bulge in the direction of movement. This type of movement is called ameboid movement. A euglena swims by means of a flagellum which is attached at the anterior end and is nearly as long as the one-celled body. This flagellum

is held straight in front, and the tip is rotated, thus pulling the organism rapidly through the water. *Euglena* has a second method of locomotion similar to that of the ameba. It is called euglenoid movement and is accomplished by a gradual change in the shape of the entire cell. When the posterior end of the body is drawn forward, the cell becomes rounded. Afterward, the anterior portion is extended, thus pushing the cell forward. Paramecium cells move constantly. They move by means of tiny, hairlike cilia which project through minute openings in the cell membrane. The cilia are arranged in rows and are lashed through the water like tiny oars.

8. The ameba lacks any definite structures for locomotion and for the intake of food.
9. When the *Anopheles* mosquito bites a malarial patient and sucks up the blood, a few specialized individuals of *Plasmodium* are also taken in with the blood. While in the stomach of the mosquito, these mature into two entirely different kinds of cells. One is an egg cell, the other is a sperm cell. After fertilization, the egg penetrates the stomach wall of the mosquito and forms a cyst. In this condition, the parasite forms spore cells which are released when the cyst erupts. Some of the spores migrate to the salivary glands of the mosquito. If the mosquito pierces the blood stream of an individual, some of the spores are carried with the saliva, which is injected into the puncture at the time of biting. After a period of growth and multiplication, the spores penetrate the red corpuscles and continue to multiply.
10. Malaria (*Plasmodium*), African sleeping sickness (*Trypanosoma*), and amebic dysentery (*Endameba*).
11. Protozoans are an important part of the food chain in ponds as a source

of food for small fish and other animals. Certain marine forms (foraminifers) form extensive chalk deposits. Others are essential in the digestive processes of cattle and other animals. Some protozoans are dangerous parasites and cause amebic dysentery, malaria, and other infections.

ANSWERS TO APPLYING PRINCIPLES AND CONCEPTS (Page 264)

1. All of the life processes performed in higher organisms are carried on, to some degree, by a single protozoan cell. Since a single cell functions as an entire organism, its structures must perform these processes without dependence on any other cells. This independence results in such complicated protozoans as the paramecium which represents, probably, the maximum development of structures within a single cell.
2. A paramecium takes in more water through its gullet than an ameba takes in while engulfing food. This requires an additional contractile vacuole. Furthermore, the ameba probably excretes some water through its membrane, while discharge of water in paramecium is limited more to the contractile vacuoles.
3. It is best to treat the malaria patient while the spores are in the blood stream and before the sexual forms of the parasite are produced. Quinine is not effective against the sexual form of *Plasmodium*.
4. Protozoans in the human intestine feed on harmful bacteria.
5. Protozoans are a vital part of the biological balance in a pond. They feed on organic matter and thus act as scavengers. They excrete carbon dioxide and, after death, add their substance to the organic content of the water. They are an important source of food for small animals.

Guide to Laboratory Investigations for Chapter 18

INVESTIGATION 18-1

Unicellular Organisms—The Protozoans

Scope of the Investigation This Investigation introduces the student to representatives of the four phyla of protists that he studied on pp. 254-263 of the text. Each of these organisms represent a variation in the development of cellular specialization and locomotion.

A close examination of each one should give the student a better understanding of how unicellular organisms perform all the cell activities studied in Chapters 5-8 of the text.

The ameba (pp. 254-256 of text) represents a primitive way of life with little specialization. As the student studies the organism, he should observe that it is actually a shapeless mass of protoplasm confined in a thin membrane. His understanding of protoplasm as a colloidal system (p. 42 of the text) should be increased when he actually observes the change in protoplasm from a sol to a gel to a sol state in the formation of pseudopodia.

The presence of plant and animal characteristics in euglena (pp. 259-261 of text) demonstrates the difficulty in classification and the reason for a third kingdom (p. 202 of the text). A flagellum for locomotion enables the organism to move more rapidly than ameba.

The paramecium the student studied on pp. 256-259 of the text is more complex than the ameba. As the student compares the organism with ameba, he should recognize that the cell has a definite shape confined by a rather rigid wall, and specialized organelles for performing all the activities necessary to maintain the organism in an active state.

Since the student may wish to continue his study of protozoans, an opportunity is provided for him to culture his own organisms. He may also wish to collect his own samples. As he continues to study his own samples, he will find that many protozoans form colonies, and that they live in many types of habitats.

Approximate time required Parts 1 and 2 will each require 45 minutes for the observations and drawings of the organisms.

Part 3 will require 45 minutes for observation and drawing of paramecium. It will often require 15 minutes or more for the methyl cellulose to diffuse through the water and slow down the paramecium. The student may make many of the observations of the organism before the methyl cellulose takes effect.

Part 4 is a long-range study that can be carried out in three weeks. However, the initial study of the cultures is made 24 hours after the samples have been collected. This Part may be started during the studies in Parts 1-3 and continued during Investigation 18-2.

Part 5 is also a long range activity and may run for several weeks. This Part may also be done with Investigation 18-2.

A Part 1 The Ameba

Suggestions for procedure. Ameba cultures may be purchased in quantities of 25-100 from biological supply houses. They may also be maintained according to the directions in Part 5 of this Investigation for use from semester to semester.

Point out to the student that the sediment in the jar contains the organisms, and that they should transfer the sediment by pipette to the slide. The low power of the microscope is suggested for study because the cell is large, and the student can usually study the whole organism under low power. The organism is thin and reducing the light makes the cell contents more visible. Students should study the cell carefully to

find the nucleus, which does not lie in the center of the cell. It is necessary for the student to use the fine adjustment to focus inside the cell when looking for a nucleus or contractile and food vacuoles that may have formed. Frequently, they may observe the contractile vacuole as it comes to the surface and contracts, expelling the liquid wastes it has accumulated. Point out to the student that pseudopodia are formed by the flowing cytoplasm as it changes from a sol to a gel state. Review the principle of a colloid and protoplasm as a reversible colloid.

Student observations—answers to questions.

- (a) In the moving tip or projection.
- (b) The protoplasm in a sol state moves in the direction of the forming pseudopodium. As it reaches the tip of the pseudopodium, it is deflected to the sides where it changes to a gel state. The gel liquefies at the rear and flows forward again as a sol.
- (c) Probably does.
- (d) If the ameba engulfs food, two lobes or pseudopodia bend around the food, enclosing it in a food vacuole.
- (e) If there is a contractile vacuole, it may contract, forcing its contents into the water.
- (f) It changes position.
- (g) The ameba is constantly changing its shape.

A Part 2 The Euglena

Suggestions for procedure. Euglena may be purchased in quantities of 25-100 from biological supply houses. They may also be maintained in cultures as suggested in Part 5 of this Investigation.

Point out to the student that the green color in the culture is due to the green pigment that is present in the euglena. A pipette is used to transfer the organisms to a microscope slide. The student should examine the slide carefully to locate a euglena that is inactive or moving slowly. When the organism has been located, he may examine it under high power. It is often difficult to find the flagellum. Reducing the light may help in seeing it. Frequently the organism has it coiled under the cell. If it is moving by the flagellum, the organism will extend it straight out in front and wave it from side to side to propel it forward. Point out that it is difficult for them to locate individual chloroplasts because the light is passing through the cell and reflecting the green color so that the cell appears green. Students should find the red eyespot and the gullet. The large nucleus is found near the center of the cell. If the student focuses carefully, he can see the cytoplasmic strands that extend diagonally across the cell.

Student observations—answers to questions.

- (a) Forward.
- (b) It moves from side to side propelling the cell forward.
- (c) Chloroplasts.
- (d) It is sensitive to light, and light is necessary for photosynthesis.
- (f) None, it is nonfunctioning in the euglena.

A Part 3 The Paramecium

Suggestions for procedure. Paramecia may be purchased in quantities of 25-100 from biological supply houses or may be cultured according to directions in Part 5 of this Investigation.

Point out that the scum on the side of the culture jars contain the paramecium so a drop of it may be put on the slide. The student should study the slide under low power to locate a paramecium. Point out that the organism seems to be moving very

rapidly. However, it is moving slowly, and magnification is responsible for what appears to be a rapid movement by cilia. Point out that cilia also line the oral groove. Have the student study the organism carefully to determine that the spiral movement of the cell is due to the presence of the cilia in the oral groove and the oblique beating of the cilia.

Paramecia are very active, and it is often necessary to quiet them with methyl cellulose. Some students may use some algae or thread to form a trap for the cells. Have the student add a drop of methyl cellulose at the edge of the cover glass so that it can diffuse into the water. This often requires 15 minutes or more. The student can continue to make his observations of the cell. The shape of the cell is very evident and the presence of cilia around the cell and in the oral groove is easy to determine. The student may not be able to find food vacuoles. If he does, he should determine that they are moving in a circular motion as they are carried by the cytoplasm. The contractile vacuoles are stationary at either end of the paramecium and contract in the same manner as they did in the ameba. Some of the students may have studied the action of the contractile vacuoles in Part 4 of Investigation 5-3. Students may not be able to observe the anal pore that is evident when material is being discharged.

The trichocysts are not too easily observed unless the student uses acetic acid or ink to stimulate the cell to explode the tiny structures that act as a defense weapon.

The various species of paramecia differ in the number of micronuclei that are present in the cell. If *Paramecium multimicronucleatum* is used, there are several micronuclei in the cell. All cells have a macronucleus.

Student observations—answers to questions.

- (a) The cilia do not beat simultaneously and beat in an oblique direction.
- (b) Yes.
- (c) No.
- (d) There is a pellicle that confines the cell contents.
- (e) Locomotion.
- (f) To draw the food into the oral groove.
- (g) In a circular motion in the cytoplasm.
- (h) They are being carried in the cytoplasm.
- (i) Canals carry water to the contractile vacuoles, and they contract, expelling their contents into the water.
- (j) The trichocysts explode, covering the cell.
- (k) The number of micronuclei will depend on the species used.

B Part 4 Diversity Among the Protozoans

Suggestions for procedure. The student should collect samples of water from several sources such as roadside ditches, puddles, lakes and ponds. Caution him to record all the data such as place collected, depth of water, and condition of the water. His sample must have a collection number assigned to it.

Have the student collect some of the material that is in the water so that the environment will be similar to that from which the organisms were collected. The jar should be filled with the water in which the plants and protozoans are found.

Caution the student to put his jars in an area of the room where it is not too hot or too bright. The cultures should be left in their new environment for 24 hours before examination.

All the cultures should be examined under low power first. Many of the organisms will be found in Fig. 18-1-a because we have used some of the more commonly found protozoans. However, it may be necessary for the students to use taxonomic keys. Jahn, *How to Know the Protozoa* is a good key for high school students to use. Students may also have to use algae keys, since many of the organisms they will find are classified by some taxonomists as algae.

Students should examine all the organisms on the slide and record the information relating to their means of locomotion, shape, and distinctive organelles.

Student observations—answers to questions.

- (a) Probably do.
- (b) Yes, there should be.
- (c) Sessile or stalked forms.
- (d) These will vary.
- (e) The organisms build up wastes in which they cannot live, food supply is exhausted, and pH of medium changes.

Interpretation. The algae represent the autotrophs in the microcosm. The protozoans, annelids, rotifers, crustacea, and others represent the heterotrophs. These organisms feed on each other. Thus, the algae supply the initial energy to an organism that is in turn consumed by another.

B Part 5 Culturing Protozoans

Suggestions for procedure. Stacking culture dishes are best for the culturing of ameba. These are deep enough to provide a large amount of surface for the water. Dishes should be filled with distilled water. Caution the student to boil the hay and wheat kernels that will provide the bacteria food. The bacteria serve as food for the ameba. The student may collect ameba from ponds. However, they do not always find ameba in their cultures. Caution the student to collect some decaying plants from the pond. These often harbor amebas. Ameba cultures should always be kept in reduced light and at room temperatures.

In culturing paramecia, the student should use stacked culture dishes if they are available. Battery jars may be used, but they are large and require a larger area for maintaining the cultures than the stacked culture dishes. It is necessary to boil hay and wheat kernels to provide food for bacteria in the culture. Point out to the student that it requires about a week for the bacteria to multiply in sufficient quantity to supply food to large numbers of paramecia. Caution the student to transfer only paramecia from his culture. Contamination with other protozoans may result in the loss of the paramecia. The student can make his own micropipette for transferring the paramecia by heating a piece of glass tubing in a burner and pulling out the tube from both ends while the glass is hot. Directions are given in the student manual. The paramecia should be transferred after two weeks to a new culture. This is necessary because paramecia cannot live in their own wastes. The cultures of paramecia should be kept in a north window if possible and at room temperature.

Euglena cultures may be maintained in a battery jar. Wheat or rice kernels boiled for five minutes provide the food for the bacteria that serve as food until the euglena have become established. Then they begin to make their own food by photosynthesis, using the mineral matter from the decaying rice or wheat kernels. If the students collect their own euglenas, caution them to examine the culture carefully since other organisms turn the water green. The micropipette that the student made for transferring the paramecia may also be used to transfer the euglenas to new cultures. Point out that this culture requires sunlight and should be kept at room temperature.

Interpretation. New cultures of each of the protozoans should be established because the organisms build up wastes that are toxic to themselves; dead organisms pollute the water and the food supplies become exhausted.

INVESTIGATION 18-2

Responses of Unicellular Organisms to Stimuli

Scope of the Investigation. In this Investigation the student actually demonstrates and observes that protoplasm is sensitive and responds to environmental conditions (p. 256 of the text). His observation of the negative response of ameba to salt crystals and ultimate plasmolysis of the cell (p. 76-77 of the text) provides a graphic demonstration of why ameba is not attracted to a medium containing a high concentration of salt.

The positive response exhibited by ameba and paramecium to the vinegar and food bears out the discussion of chemical attraction on pp. 256 and 258 of the text. Further evidence of chemical attraction is demonstrated in the ingestion of a carmine red solution by paramecia. The organisms apparently cannot distinguish between the solution and food. However, the acid nature of the solution attracts the organisms to it (p. 258 of the text) and the solution is ingested and a food vacuole is formed.

The student should gain a better understanding of the avoiding reaction (p. 258 of the text) as he observes the behavior of paramecia in an electrical field and their response to heat and touch. The avoiding reaction is also demonstrated by *Vorticella* and *Stentor* in the study of touch.

The mechanism of exploding trichocysts is observed by the student as he adds ink to the medium containing paramecia (p. 258 of the text).

The fact that light is an important factor to the euglena in carrying on photosynthesis is demonstrated as the student finds the organisms concentrated in the lighted area of a culture dish and in the lighted portion of the microscope slide. However, the student discovers that other unicellular organisms such as ameba avoid lighted areas.

From his studies of the behavior of various unicellular organisms, the student should become aware of the fact the responses he observed in each organism were related to the physiological activities of the cell.

Approximate time required. Section 1 will require 40 minutes to complete. Sections 2 and 3 can be completed in 40 minutes if the apparatus for testing paramecium response to electricity is set up before the beginning of the period. The four cultures of paramecia should also be prepared to remain in their position for 10 minutes while the study of the response to electricity is in progress. Sections 4, 5, 6, and 7 will require 40 minutes to complete. The culture of euglena for Section 6 may be prepared and left for 10 minutes while students are doing Section 5.

B Part 1 Responses to Stimuli

Suggestions for procedure. All of the cultures—ameba, paramecium, *Vorticella*, *Stentor* and euglena—may be purchased from biological supply houses. Ameba, paramecium, and euglena should be available from Investigation 18-1. *Paramecium multimicronucleatum* is recommended for study because it is large enough to be observed easily.

The quantity of salt crystals is not critical, any amount will cause a negative response and ultimate plasmolysis in ameba. Household vinegar is used for the experiment with the ameba and paramecium. Point out to the student that vinegar is acetic acid. The student may check the pH to determine that it is acidic.

Use a pipette to drop the ink at the edge of the cover glass. The student should watch the cell carefully as the ink diffuses into the water. As he watches, the trichocysts will be exploded, and the cell will die from the presence of the ink.

The student should check the pH of the carmine red solution to determine whether

it is basic or acidic. This solution is prepared by adding carmine powder to a boiling 45% acetic acid solution until the solution is saturated. Have the student observe the action of the cilia in the oral groove and the ultimate ingestion of the carmine solution. Point out that the organism is responding to the chemical nature of the solution and that it does not recognize a substance as food.

The apparatus for testing paramecium response to electricity should be prepared before class. This Section might be done as a demonstration if time is a critical factor in this Investigation.

The student must follow the directions carefully in preparing the tubes of paramecia for Section 3 so that light is not a variable factor in the study. Be sure to let the tubes rest for 10 minutes.

The culture of euglena should stand for 10 minutes so that the organisms have an opportunity to respond to the light. This set-up may be prepared and allowed to stand while Section 5 is in progress.

Student observations—answers to questions.

- (a) The ameba moves away from the crystals.
- (b) Cell protoplast shrinks.
- (c) The water molecules move from the region of higher concentration in the cell to the region of lesser concentration outside the cell.
- (d) Movement is toward the acid.
- (e) Bacteria live in an acid medium.
- (f) Many paramecia are collected around the debris.
- (g) Trichocysts explode. Students may observe dark areas in the cell where food vacuoles have formed around the ink.
- (h) Food ball is formed in the oral groove and a vacuole is formed around it as it passes into the cytoplasm.
- (i) At the negative pole.
- (j) Yes.
- (k) The charge on the surface of the paramecium is positive.
- (l) In the top of the tube.
- (m) In the top of the tube.
- (n) Along the upper edge.
- (o) Along the upper edge.
- (p) No.
- (q) Move away.
- (r) Contracts.
- (s) The paramecia alter the direction in which they are moving.
- (t) Pseudopodia are formed in region away from the spun glass fibers, and the ameba moves away from the fibers.
- (u) In the area of the light.
- (v) Eyespot.
- (w) As energy for photosynthesis.
- (x) Move to area of light.
- (y) Move to darkened area.

Interpretation. Bacteria serve as food for both the ameba and paramecium. Bacteria live in an acid medium, therefore, these organisms have a positive response to the acid environment.

The presence of positive charges on the surface of the paramecium may be related to the movement of essential substances across the membrane. Their negative response to gravity could be due to the fact that the oxygen supply is more plentiful at the surface of the tube. Food supply could also be a factor causing them to be found on the surface of the medium.

Heat and light are both factors that are harmful to the ameba and paramecium; thus, the avoiding reaction.

The trial-and-error response of movement in ameba, paramecium, *Vorticella*, and *Stentor* aid the organisms in finding food and escaping from their enemies. The explosion of the trichocysts also demonstrates a protective measure.

Light is essential to the euglena in carrying on photosynthesis; thus, the organism is attracted to the light. However, it is possible for the euglena to live in total darkness since it can absorb organic matter through its cell membrane.

Chapter 19

The Fungi

Examples of fungi are found everywhere and a request to the students to collect them will usually elicit a rewarding response. The concept of the nutritional relationship between a fungus and its food source is of prime importance.

Bread mold is a familiar organism and a good example to use in the study of fungi. It has several kinds of hyphae and they can be easily distinguished with a hand lens and a microscope.

Rusts and smuts are of great economic importance, especially in grain-growing regions. The cycles of these fungi and, in the case of rusts, alternate hosts, should be emphasized.

Films or Kodachrome slides on the mushroom may add to your presentation of the fungi. Special reports on mushroom growing and cookery may be interesting to the students.

P. 267, left column: Have students bring in samples of moldy bread, oranges, and lemons. Put samples of these under a hand lens for observation, widefield stereoscopic, or compound microscope. Bring in a wrapper of bread or cake to show the use of mold retardants like calcium propionate.

P. 269, Fig. 19-6: The remedy for mildew in the garden is to dust with sulfur, especially after rain. Students can report on how man fights plant diseases—use of sprays and disposing of garden debris.

P. 270, left column: The history of yeast's use makes interesting material for the teacher to approach the lesson. Models

of bread making have been obtained from the tombs of ancient Egyptians, who used wild yeasts. Students may wish to bring in samples of homemade yeast bread and coffee cake. Bread and its use in religion make an interesting topic: the unleavened bread of the Hebrews, the Christian use of bread in Communion. Samples of unleavened bread can be brought to class.

P. 271, left column: Plant diseases may also have vectors. The beetle, for example, carries the Dutch elm disease. Black spores known as ergot are sold in the open market in Mexico. They are poisonous in large doses. In France a baker was brought to trial for using flour infected with ergot spores, which caused severe illness in his customers.

P. 273, left column: Alternate hosts are important. In regions of the U.S. where the native white pine grows, people are prohibited from raising currants or gooseberries because they are an alternate host for the white pine blister rust. We must import black currant jam and juice from Europe where the pine does not grow. Have students bring in samples of the jam.

P. 274, right column: One superstition in connection with mushrooms is that if you place a quarter in water with the mushroom, it will turn black if the mushrooms are poisonous. Different species taste very differently. Dried mushrooms sold in Chinese stores have a very different flavor. In France truffles have been used for centuries, and some masterpieces have

been painted of scenes showing the use of pigs to find the mushroom by smell.

P. 275, left column: Puffballs get their name from the fact that when ripe and pressed, the spores escape in a cloud from an opening at the top of the ball.

P. 275, right column: Discuss athlete's foot. Students are amused if told they have a plant growing on their feet.

Suggested Films

Fungi (col, 28 min) AIBS McGraw-Hill

Fungi (b&w&col, 16 min) EBF

Reproduction (col, 28 min) AIBS McGraw-Hill

Simple Plants: Algae and Fungi (b&w&col, 13½ min) Cor

MAJOR CONCEPTS

1. Since the fungi lack chlorophyll, they are either saprophytes or parasites.
2. All fungi produce spores that are carried either by air or by water. Many also reproduce sexually.
3. Fungi are widespread because of the enormous number of spores they produce.
4. Molds are familiar fungi and require organic matter, moisture, warmth, and darkness to thrive.
5. Two physiologically different types of *Rhizopus* can be illustrated by sexual reproduction.
6. Many fungi, such as the downy mildews, rusts and smuts, are parasitic and injure the plants on which they grow.
7. Many fungi are used commercially in making bread and cheese.
8. Some fungi, such as the mushroom, are edible and many are poisonous.
9. The imperfect fungi reproduce only asexually and many are parasitic in man, animals, and plants.

ANSWERS TO QUESTIONS FOR REVIEW (Page 276)

1. All fungi are nutritionally dependent plants, requiring contact with a host or other organic food supply.
2. Myxomycetes, Phycomycetes, Ascomycetes, Basidiomycetes, and Deuteromycetes. The last four classes mentioned above are true fungi.
3. The mycelium of a fungus consists

of a tangled, spreading mass of colorless threads, the hyphae. They may be of various sorts, as in bread mold (*Rhizopus*).

4. The hyphae of bread mold (*Rhizopus*) may spread over the surface of the food supply. These hyphae are the stolons. Tiny rootlike hyphae grow from the stolons and penetrate the food supply and absorb nourishment. These hyphae are called rhizoids. The third kind of hyphae are erect and extend upward where they produce a sporangium and support it until the spores are released. These hyphae are called sporangiophores.
5. Spores of bread mold and other molds are present in the air. If a spore settles on a piece of bread or other suitable food supply and if other growth conditions are present, the spore germinates and produces a hypha, which continues growth into the mold mycelium.
6. *Penicillium* molds are valuable because some species provide the drug penicillin, and others are used in the processing of flavored cheeses.
7. Downy mildews are internal parasites which cause considerable damage to the tissues of the host organism. Powdery mildews are external parasites.
8. A bud begins as a small knob pushing out from the yeast cell. This bud, or daughter cell, grows rapidly, and if conditions are favorable, it may produce another bud while it is attached to the mother cell.
9. The formation of alcohol during sugar fermentation is an important industrial process. Carbon dioxide, released during fermentation, is important in the baking industry.
10. In the late spring and early summer, surface hyphae of wheat rust discharge reddish-orange, one-celled spores called uredospores. Later in the summer, these same hyphae produce a second spore. This is a black, two-celled spore with heavy, thick protective walls. Black spores are referred to as teliospores. Early in the spring, both cells of the telio-

spores germinate, producing four-celled basidia. A new spore called a basidiospore forms on each of the four cells of the basidium. If a basidiospore lodges on a leaf of the common barberry, complicated tissue changes will occur in the leaf of the barberry, and tiny cups containing rows of a fourth kind of spore will appear on the leaf. These new spores are the aeciospores.

11. The basidium stage and the production of basidiospores relates corn smut to the rusts.
12. The reproductive part of a mushroom develops as a bud, or button, on the mycelium, and is composed of a mass of hyphae packed tightly together. This mass grows upward and opens into the familiar mushroom above the ground. Spores form at the ends of basidia on the gill surfaces.
13. The reproductive structures of puffballs never open to discharge their spores.
14. Ringworm, athlete's foot, barber's itch, and thrush.

ANSWERS TO APPLYING PRINCIPLES AND CONCEPTS (Page 276)

1. The mildews grow better when there is sufficient moisture and a favorable temperature. Both the moisture content of the atmosphere and the temperature vary from summer to summer.
2. The yeast plants produce zymase, which acts on the sugars during respiration. This is an anaerobic process and can take place in an airtight container.
3. Yeast plants produce vitamin B₂, or riboflavin, which is essential to the health of the skin.
4. More of the teliospores survive in a mild winter.
5. Their mycelium has exhausted the organic matter in one spot and has moved into the unused organic matter in the soil or host material. New mushrooms are produced at the outer edge of the growing ring of mycelium. The newest and most active molds grow at the outer edge of a colony so as to obtain nourishment.

Guide to Laboratory Investigations for Chapter 19

INVESTIGATION 19-1

Structure and Distribution of Common Molds

Scope of the Investigation In this Investigation the student will actually watch the growth of a bread mold following inoculation by spores from the air. The microscopic study of the mold will reveal its structure, which he studied on pp. 266-267 of the text.

He will become familiar with the structure of *Penicillium* and *Aspergillus* as he studies their growth on gelled agar and under the microscope (Fig. 19-2 of the text).

In his study of *Neurospora*, he is growing and examining a mold whose study has revealed some very important concepts in genetics (pp. 149-153).

The student is also provided an opportunity to extend his study of molds by collecting them from various sources and identifying them.

Approximate time required Four days will be required, sometimes more, for the bread mold to develop in Part 1. The exposure time is 60 minutes and can be done while the student is working in Part 2. It will require the student 50-60 minutes to examine and draw the bread mold.

If the Petri dishes have been sterilized and poured with the sterile Saubouraud's dextrose agar, the plates can be inoculated with each of the organisms in 10 minutes. If the student pours his own agar plates, allow an additional 10 minutes for the agar to gel. The organisms require at least a week to grow. Examination of the organisms will require 15 minutes for each one.

Part 3 may run concurrently with Parts 1 and 2. If the Petri dishes have been sterilized and poured with the sterile Bacto-*Neurospora* agar, the plates can be inoculated with *Neurospora* spores in 10 minutes. The plates may be examined after 24 hours. It will require 20 minutes to complete the examination and collect data.

Part 4 may extend over several weeks and run concurrently with other studies of fungi.

A Part 1 Growing Bread Mold

Suggestions for procedure. The student can easily collect bread mold spores from the air in his classroom. Caution him against having water in the bottom of the dish in which he is growing the mold. The exposure should be made for 60 minutes. If the period is not this long, the student may return to cover the dish or the teacher may do it for him. In that case, the teacher will need to put the dish in a dark, cool place. The mold requires at least a week to grow. Time may be saved in the initial exposure if a culture of bread mold is available and an inoculation can be made in 5 minutes.

Have the student examine the mold on the bread with a hand lens and observe the erect hyphae and sporangia. Students will have difficulty in transferring a whole plant to the microscope slide. He should examine the slide carefully to try to find an entire plant. After he has observed the three kinds of hyphae which he should find on the slide, he may fill in the table.

Have the student smell the bread and determine the cause of the odor if one is present.

Student observations—answers to questions.

- (a) Mycelium.
- (b) Absorption of the digested material on which it is living.
- (c) Streaming cytoplasm within the stolons carry food.
- (d) The student should detect an odor.
- (e) Enzymes produced by the mold cause a chemical change in the bread.
- (f) They are exposed to the air so that when they rupture the spores can be carried to a new host.

A Part 2 Blue and Green Molds

Suggestions for procedure. The Saubouraud's dextrose agar should be prepared, sterilized, and poured into sterile Petri dishes before class. The agar is poured to a greater depth than nutrient agar for growing bacteria. The *Penicillium* and *Aspergillus* cultures may be purchased from a biological supply house unless someone has a pure culture on hand. It may be necessary to demonstrate the technique for rotating the sterile inoculating loop on the agar plate. A hand lens is used for the examination of the colony. For detailed study, the student puts the Petri plate with the culture on it under the microscope.

Student observations—answers to questions.

- (a) Greenish, raised mat.
- (b) Dark green mat.
- (c) The hyphae are long filaments of cells.
- (d) The hyphae of *Penicillium* have cross walls; bread mold hyphae lack cross walls and are tubular.
- (e) Produced in chains at the tips of the hyphae; resemble tiny brooms.
- (f) The hyphae of *Aspergillus* are long filaments with cross walls.
- (g) Yes.
- (h) They are both members of the Ascomycetes, so the structure should be the same.
- (i) Produced on globose hyphal tips.
- (j) No.

- (k) The differences in the formation and location of the conidia are the characteristics that separate the two genera from each other.

B Part 3 Culturing *Neurospora*

Suggestions for procedure. The culture of *Neurospora* may be purchased from a biological supply house. The strain that is used is not critical. The Bacto-*Neurospora* agar medium can be purchased from a biological supply house or the student may prepare his own medium by dissolving 3 gm of glucose, 0.5 gm of KH_2PO_4 , 0.7 gm yeast extract and 2 gm nutrient agar in 100 ml of water. The medium should be brought to a boil, bottled and sterilized in an autoclave for 15 minutes at 15 pounds pressure. If students prepare their own media, it will be necessary to allow an additional 15 minutes for the exercise. Sterile plates should be poured with the agar before class so that the inoculation of the plates can be done at the beginning of the class. The plates are inoculated in the center with the spores and incubated at room temperature for 24 hours.

Examination of the plate is to be done with the Petri dish cover off. After the student has located an advancing hypha, he should place a cover glass right on top of this hypha so that half of the glass is over bare agar. Have the student press the cover glass gently to remove air and allow moisture in the agar to move up under the glass. The student should place the plate on the microscope stage and with the lid off examine the organism under high power.

Instruct the student to examine the plate to locate a zone of hyphal tips that are growing. As he studies the filament, he will probably conclude that there are walls in the filament. Have him study the streaming protoplasm to determine whether these are true walls. He should observe that the protoplasm is moving more rapidly at the tips than in the older cells. It is not possible to see a nucleus. As the student studies growing *Neurospora* he should conclude that growth occurs only in the hyphal tips.

Student observations—answers to questions.

- (a) There will be a filamentous growth of *Neurospora*.
- (b) The hyphal tip is growing across the Petri plate.
- (c) Filamentous with branching.
- (d) Yes.
- (e) No.
- (f) Protoplasm is moving through them.
- (g) Yes.
- (h) The openings in what appears to be walls must be larger in the tips.
- (i) Should locate a vacuole.
- (j) The cells at the tip of the hypha.

B Part 4 Collection and Identification of Different Species of Mold

Suggestions for procedure. The student may find molds on some of the food items that are in his refrigerator or he may ask his grocer for fruits, vegetables, or meat that have mold developing on them. Since there are often several species of mold on one food item, the student might wish to transfer mold spores to sterile Saubouraud's dextrose agar plates. These cultures can be grown over a period of a week and will be available for study as time permits. If a transfer is made, caution the student to identify the plate as to the source of the mold. All data relating to the molds should be recorded carefully in the table provided.

Interpretation. Answers should include the fact that citrus fruits are frequently contaminated by the blue and green molds. Bananas are often contaminated with molds. Cheeses are contaminated with blue and green and black molds. Orange pigmented molds are found frequently on citrus fruits.

INVESTIGATION 19-2

Study of Yeast

Scope of the Investigation In this Investigation the student observes structural differences (p. 269 of the text) between the yeast plant and the molds he studied in Investigation 19-1. A day to day study of growth of yeast cells emphasizes the fact that favorable conditions result in the formation of buds (pp. 269-270 of the text). The fact that yeast plants are capable of fermenting simple sugars is also demonstrated (p. 270 of the text).

Approximate time required Each of the Parts in this Investigation extends over a 24 hour period. Therefore, the preparation of the yeast culture and the various sugar and starch solutions may be done on the same day. Time may be saved by dividing the class into teams of 4 or 5 and assigning them to the preparation of the various solutions. The preparation of each solution will require a minimum of 10 minutes.

The examination of the yeast culture in Part 1 and drawing and counting of the cells will require 15 minutes on the first day.

The examination, counting, and drawing of the yeast cells in Part 1 will require 15 minutes on the second day. The examination of the fermentation tubes and recording of data in Part 2 will require 50-60 minutes on the second day. Time may be saved by having each team that prepared the solutions make the examination and combine the data for the entire class.

A Part 1 Study of Yeast

Suggestions for procedure. If fermentation tubes are not available, flasks or small milk bottles may be used. The package of yeast may be purchased at the grocery.

In filling the fermentation tube with the yeast culture, the student should hold it at a slight angle so that the culture fills the tube and extends to the bulb, as shown in Fig. 19-2-a. Caution the student not to leave air at the top of the tube since he will possibly interpret air in the top as evidence that fermentation has occurred. The tubes, flasks, or bottles containing the yeast culture should be placed in an incubator at 35-37°C if one is available. If not, a warm place in the room will serve for the incubation.

Iodine or methylene blue is used to make the parts of the yeast cell more distinct. It will not be possible for the student to count all of the cells, so the number on the first day is an estimate.

The forcing of the yeast solution into the bulb of the fermentation tube is visible evidence that gas has been produced during fermentation. If bottles or flasks are used, the presence of bubbles or foam on the top of the culture serves to indicate gas production.

Students should examine the slide very carefully to locate cells with buds and should study the cells for the formation of large vacuoles that form during the growth period. Again, the count they make of the cells in the field will be an estimate.

Student observations—answers to questions.

- (a) Answers will vary. Should be a rather large number.
- (b) The yeast culture has been pushed into the bulb of the fermentation tube. If a flask was used, gas bubbles will be present.
- (c) Sour, alcohol.
- (d) Sour.
- (e) Carbon dioxide caused the solution to become acidic (sour).
- (f) Alcohol and carbon dioxide.
- (g) Answers will vary. Should be an increase over the previous day.

- (h) There should be a much larger number.
- (i) The cells have been reproducing under favorable conditions.
- (j) The cells have increased in size and large vacuoles fill the center of the cells. Many of the cells have buds.

B Part 2 Fermentation by Yeasts

Suggestions for procedure. Pure cultures of *Saccharomyces cerevisiae* and *Saccharomyces ellipsoideus* may be purchased from a biological supply house. To prepare the 200 ml of each solution, dissolve 20 ml of each one in 180 ml of water. The brom thymol blue solution is prepared by dissolving 0.05 gm of brom thymol blue in 99.95 ml of water.

Since the student is working with a large number of tubes, he must use care to identify them properly. It is better to use teams of students since it reduces the number of fermentation tubes needed and cuts down on the time required. The tubes should be filled in the same manner as suggested in Part 1. Again, caution the student not to leave air in the top of the tube. Warn the student to use a clean pipette for introducing the yeast suspension to the fermentation tubes. Tubes should be incubated at 35-37°C for 24 hours in an incubator, if one is available. If not, put the tubes in a warm place in the room.

The results of the examination of the tubes on the second day should be recorded on the table provided. The presence of gas is evident when the culture has been forced into the bulb of the fermentation tube. Further evidence of the presence of carbon dioxide is demonstrated in the color change of the brom thymol blue indicator from blue to yellow.

Student observations—answers to questions.

- (a) Gas bubbles were formed on the surface.
- (b) The culture was forced into the bulb of the fermentation tube.
- (c) It will change from blue to yellow in some fermentation tubes.
- (d) That the solution has become acidic.
- (e) The sugar.
- (f) There was no color change in the tubes containing the starch.
- (g) Alcohol.
- (h) Sour.
- (i) The chemical change occurring during fermentation results in the release of carbon dioxide as a fuel product.

Interpretation. The answers will depend upon student observations. Both of the strains of yeast ferment the sugar solutions. There should be a greater amount of gas produced in the tube containing *Saccharomyces cerevisiae* and maltose than in the tube containing *Saccharomyces ellipsoideus* and maltose.

INVESTIGATION 19-3

The Mushroom

Scope of the Investigation The student continues his study of fungi by studying one of the most familiar of the fungus plants, the mushroom. In his study he will observe that the more familiar plant body is composed of tightly packed hyphae and that a vegetative body composed of many silvery hyphae grows below the surface of the soil (pp. 273-274 of the text). His study of the gill structure and spore print will give

him a better understanding of spore formation and dispersal by the mushroom (p. 274 of the text).

Approximate time required The entire Investigation can be completed in 50-60 minutes. The mushroom cap should be placed gills down on a piece of white paper on the day previous to the study of a spore print. This is best suited to a demonstration. It is not necessary for each student to make a spore print.

A Part 1 Structure of a Mushroom

Suggestions for procedure. The fresh mushrooms may be purchased from the grocery. Charts of the structure of the mushroom may also be used. The student will not be able to see the vegetative hyphae that grow below the ground. Section several of the fresh mushrooms lengthwise through the stipe and cap and remove the caps from others. Members of the class may exchange the pieces after they have studied them. Information concerning the structure of the mushroom is contained on the drawings.

A Part 2 Microscopic Structure of a Mushroom Gill

Suggestions for procedure. A wet mount of the portion of the gill should be prepared. Students will experience some difficulty in finding the basidia and basidiospores. These will be in various stages of development. If you are using the common field mushroom, students should find four basidiospores (two if using the cultivated mushroom).

A Part 3 Mushroom Spore Print

Suggestions for procedure. This is best suited to a demonstration. The student or teacher should remove the cap from the mushroom and lay it gill side down on a sheet of white paper so that the mature spores will be discharged on the paper. This spore print set-up should be left overnight and examined at the next class meeting.

Student observations—answers to questions.

- (a) Answers will vary according to the species of mushroom used. They may be pink, black, purplish, brown, or white.
- (b) The mycelium forming the vegetative body of the mushroom lies just below the soil and when conditions are favorable, tiny knobs form on the mycelium just below the ground. These knobs of tightly packed hyphae develop into the portion of the plant that we call the mushroom.

Chapter 20

The Algae

A few common algae and some with unusual reproductive processes have been chosen for this chapter. These representatives, and others from freshly collected material or preserved material, should be observed in the laboratory. Almost every area has some place (a stream, pond, irrigation ditch, horse trough, or aquarium) where algae are growing. Observations should first be made as to the growth habit and visual appearance of an available alga.

Then, in the laboratory, added observations can be made using a microscope.

The variation in size of algae may be observed in a film and in pictures. A class discussion should bring out the differences in color of algae and the correlation of the depth at which a particular alga grows and its color. A short explanation of the wavelengths of light and the filtering action of water will increase the student's understanding.

A collection of algae from many sources may be kept in gallon jars and various phases in the life cycle may be observed. The concepts of alternation of generations and sexual and asexual reproduction should be well understood by each student, as they will be treated again in respect to different organisms.

The symbiotic relationship observed in the lichen should be discussed. Many examples of this interesting association are available in most areas.

P. 278, Fig. 20-1: Since *Oscillatoria* gets its name from its motion, it is interesting if fresh specimens are available from a pond and are observed under the microscope.

P. 282, right column: The habit of *Spirogyra* of conjugating and producing zygotes makes it possible for the plant to survive the harsh winters typical of some parts of this country.

A holdfast is typical of some marine algae. During severe storms these algae may be torn loose from the rocks and cast up on shore.

Explain Figs. 20-4 and 20-5, using the open text.

P. 287 left column: Diatomaceous earth may be obtained through a student or a biological supply house. If some is put on a slide for viewing, the shapes of some of the plant shells can be seen. Many seaside cliffs in California are formed of diatomaceous earth, and it is added to some toothpastes to give abrasive action. Thus you can admire the earth or put it in your mouth!

P. 287, right column: Some peoples depend on seaweed for food. Korea and Japan are large consumers. The algae are eaten in dry sheets or used as a basis for soup. Algae can be obtained in Chinese food stores or sometimes in some so called health food stores.

P. 289, Fig 20-8: Irish moss and other algae are used for making desserts. Algin, a derivative, is used in dentrifices, brushless shaving creams, hand lotions, and in tooth extraction. It reacts with the calcium in the blood to form a seal that stops bleeding.

P. 290, right column: Some lichens are still used for dyes. The most common example is from the chemistry lab, where litmus is used to indicate the acidity or al-

kalinity of substances. The chief source of this dye is *Rocella tinctoria*. Lichens also fix odors in perfumes. Lichens contain acids not found in other plants. The presence of these helps in identification of species.

Suggested Films

Algae (b&w&col, 16 min) Ind

Algal Reproduction (col, 28 min AIBS McGraw-Hill

Simple Plants—The Algae (b&w&col, 18 min) EBF

MAJOR CONCEPTS

1. Algae are the most abundant form of vegetation in aquatic environments and are, therefore, an important food for many animals. Some grow on barks of trees, fence posts, or wet stones.
2. Some algae are unicellular and some may form a multicellular organism more than 100 feet long. Some form colonies, each cell living independently.
3. It is likely that algae and fungi evolved from a common ancestor.
4. All algae have chlorophyll and photosynthesize, but the green is often masked by other pigments.
5. Algae reproduce sexually and asexually.
6. The blue-green algae, the viruses, and bacteria, are often considered among the most primitive plants; they have no organized nucleus.
7. The cells of green algae have a definitely organized nucleus.
8. Some filamentous algae reproduce sexually by conjugation, and others release flagellated gametes. Sexual reproduction in *Oedogonium* involves heterogamy.
9. Alternation of generations provides for a variety of spores by meiosis in the sporophyte, as well as a variety of possible combinations of genes by mitosis in the same gametophyte.
10. The diatoms form walls of silicon dioxide and manganese and when they die the skeletons sink to the bottom. Diatomaceous deposits many feet thick are mined for use as scouring powders and refining processes.
11. Algae have many industrial uses.

12. Some algae are being considered for use in several ways during space flights.
13. Lichens exemplify a symbiotic relationship between a fungus and an alga.

ANSWERS TO QUESTIONS FOR REVIEW (Page 291)

1. Algae, unlike fungi, always contain the pigment chlorophyll, and can carry on photosynthesis.
2. Algae lack the tissues and organs of more complex plants.
3. Cell division in a colonial alga increases the size of the colony.
4. Blue-green (Cyanophyta), green (Chlorophyta), golden-brown (Chrysophyta), brown (Phaeophyta), red (Rhodophyta), and the dinoflagellate phylum (Pyrrophyta). Examples of the groups in the order named are: *Nostoc*, *Gloeocapsa*, and *Oscillatoria*; *Protococcus*, *Spirogyra*, and *Chlorella*; diatoms; *Fucus* and kelps; red algae (no specific forms are given in the chapter); last group, dinoflagellates and cryptomonads.
5. Blue-green algae become poisonous when they die and thus pollute water, making it unfit for humans. They also give a "fishy" or "pigsty" odor to the water.
6. In addition to chlorophyll, the blue-green algae contain a blue pigment, phycocyanin.
7. Located in a filament of *Nostoc* is a heterocyst, which is an empty cell with thick walls and pores at either side where it joins other cell walls. The pores of the heterocysts form a weak link in the filament, enabling it to break into shorter pieces.
8. A *Nostoc* ball is composed of a gelatinous matrix in which many twisted filaments composed of tiny spherical cells are embedded.
9. *Gloeocapsa* cells secrete a slimy sheath. A colony of *Gloeocapsa* may contain hundreds of cells, joined by their sheaths in a gelatinous layer.
10. The gentle swaying back and forth of a filament.
11. In addition to chlorophyll, an orange pigment, carotene, and a yellow pigment, xanthophyll, are present in the cells of green algae.
12. *Protococcus* lives on shaded tree bark and other surfaces, not in water, where most algae live.
13. *Chlorella* is of interest to biologists because several of its species live in cells or tissues of one-celled animals, sponges, and jellyfish. It has been the subject for research in the study of photosynthesis as well as in studying alga cultures as a possible source of human food.
14. The presence of the spiral ribbon-like chloroplast identifies *Spirogyra*.
15. During conjugation of most species of *Spirogyra*, the cells of + and - filaments unite by forming conjugation tubes. The content of a - cell moves through the conjugation tube and combines with the contents of a + cell to form a zygote.
16. Gametes are smaller than zoospores and have two flagella. Zoospores have four flagella.
17. The occurrence of two distinct stages in the life of an organism is called alternation of generations. In *Ulothrix*, one generation produces zoospores which swim through the water. When a zoospore reaches a favorable place, it grows into a filament recognized as *Ulothrix*. This new generation produces gametes which are released into the water. Gametes from separate cells fuse, and the resulting zygote settles to the bottom where it forms spores from which filaments of *Ulothrix* develop. Thus, one generation reproduces asexually and one generation reproduces sexually.
18. A diatom has a valve, or shell, composed of two parts, one fitting over the other. The valve is composed of a silicon compound and contains many crossline markings.
19. Diatomaceous earth is valuable as insulation material, as ballast for roads, as filters in gasoline refining, and in various cleansing agents.
20. While some red and brown algae live in fresh water, most of them live in shallow oceans attached to rocks along the coast or in tidepools.

21. Algae are an essential part of the environment of aquatic life. In addition, many forms may be used as a source of food. They are important, also, in water pollution, since they add organic matter to the water when they die and decompose. Salt-water algae may be used as fertilizer.
22. In lichens, the alga derives moisture from the fungus, while the fungus obtains its nourishment from the alga, in a mutually beneficial arrangement.
5. Conjugation in *Spirogyra* is primitive because gametes are not formed.
6. Sexual reproduction in *Oedogonium* involves only certain cells in a filament.
7. Each cell of *Spirogyra* is identical to adjacent cell and can conjugate with a cell of another filament. In *Ulothrix*, cells may produce zoospores under ideal conditions, while at other times *Ulothrix* cells may produce gametes. There is no structural difference between the gametes. In *Oedogonium*, only certain cells are involved in sexual reproduction and there is a structural difference between the male and female gametes. During the process of sexual reproduction two haploid cells (gametes) fuse to form the diploid zygote. In the formation of the gametes during meiosis there is a reshuffling of the chromosomes. Then, when gametes fuse, recombination occurs, forming a new combination of genes not present in either parent. The evolutionary significance of this genetic variation has already been discussed.

ANSWERS TO APPLYING PRINCIPLES AND CONCEPTS (Page 291)

1. Chlorophyll is essential for photosynthesis, and all algae carry on photosynthesis.
2. Each of the 50 cells is an individual plant.
3. Spores are asexual bodies and are capable of forming a new organism directly. Gametes are sexual bodies and must unite during fertilization and form a zygote before cell division and formation of a new organism can occur.
4. The cells of blue-green algae are considered primitive because they
8. During the process of sexual reproduction two haploid cells (gametes) fuse to form the diploid zygote. In the formation of the gametes during meiosis there is a reshuffling of the chromosomes. Then, when gametes fuse, recombination occurs, forming a new combination of genes not present in either parent. The evolutionary significance of this genetic variation has already been discussed.

Guide to Laboratory Investigations for Chapter 20

INVESTIGATION 20-1

The Algae

Scope of Investigation This Investigation introduces the student to a new phase of biology; the study of independent microscopic plants. As he studies the various groups of algae he will find a wide variation in color pigments and in structural and reproductive characteristics. His study will begin with the less specialized representatives of the blue-greens that he studied on pp. 278-280 of the text and continue through the greens (pp. 280-286), diatoms (pp. 286-287) and the red and browns better known as seaweeds (p. 287).

His study of the green algae introduces him to the concept of sexual reproduction as he observes conjugation in *Spirogyra* and formation of gametes in *Ulothrix* and *Oedogonium* (pp. 281-286) of the text).

Approximate time required The student should be able to complete the observations and drawings in Part 1 in 50-60 minutes. Part 2 will also require 50-60 minutes for observations and drawings of the green algae. Students may experience some difficulty in finding the material under the microscope, and it may be necessary to allow more time for Parts 1 and 2. Parts 3 and 4 can be completed in 40 minutes.

A Part 1 Blue-Green Algae—Cyanophyta

Suggestions for procedure. Cultures of *Nostoc*, *Anabaena*, *Oscillatoria*, and *Gloeocapsa* may be purchased from a biological supply house.

In examining the section of a *Nostoc* ball caution the student to cut a tiny section of the ball and mount it in a drop of water. The material may be mashed with the dissecting needles to separate the filaments. If the student has difficulty locating a single filament, have him examine the edge of the mounted material. Emphasize the fact that these chains of *Nostoc* cells form the *Nostoc* ball by gelatinous secretions from their cells. The student should examine the entire slide to locate the heterocysts that are usually found in their specimen if they are patient and examine the slide carefully.

The examination of *Anabaena* cultures will reveal similarities and differences between *Anabaena* and *Nostoc*. The students may find spores that are separate from the chain of *Anabaena*. They should note that the spore is elongated and has a thick wall around it. The location of the spore in a filament is an important characteristic in separating *Anabaena* from other filamentous blue-green algae.

The culture of *Oscillatoria* often contains more than one species. This provides an opportunity for the discussion of the structural characteristics used to differentiate one species from another. If the student can find living material, he will be able to observe the swaying motion of the filament. Point out that apical cells will not always be present on the filament, since many are broken or have fragmented prior to their collection. The concave cell is an interesting cell formed in many of the filaments. Point out that this is a weak area and is the point at which the filament often breaks apart.

As the student studies *Gloeocapsa*, he should discover another type of colony formation. He should reduce the light since the colony is thin and look for the numerous concentric rings that are present. He should study the rings and determine, if he can, which cells were responsible for their formation. Point out that each of the cells lives an independent existence although it lives in a colony.

Student observations—answers to questions

- (a) Resembles a peeled grape, blue green in color and gelatinous.
- (b) Distributed.
- (c) The student probably will not find heterocysts in all filaments.
- (d) There is often more than one heterocyst in a filament.
- (e) Filament consists of a chain of round cells with heterocysts.
- (f) Distributed.
- (g) Yes.
- (h) It produces spores, does not form a gelatinous ball, and does not have a gelatinous matrix.
- (i) Apical cell is not always tapered to a length equal to the width of the other cells and some of the cells are broad while others are narrow. They differ in color from dark blue black to a bright blue.
- (j) Cells are round, lack a definite nucleus and organized plastids. The sheath may resemble the capsule formed by some bacteria.
- (k) The cells contain chlorophyll.

A Part 2 Green Algae—Chlorophyta

Suggestions for procedure. The cultures of *Protococcus*, *Spirogyra* (living or preserved conjugative and vegetative forms), *Ulothrix*, and *Oedogonium* may be purchased from a biological supply house. The student may be able to collect the *Protococcus* and *Spirogyra* material. If *Spirogyra* is collected in the late spring, conjugative material can often be found.

Caution the student to use care in removing the *Protococcus* cells from the bark. Many students will draw bark material for the cells. The student may experience diffi-

culty in locating colonies. He should focus carefully to determine whether the cell grouping is a colony or cells that have washed over each other.

In studying *Spirogyra*, the student should examine the filament carefully to locate the position of the pyrenoids, the suspended nucleus in the center of each cell, and to determine that the filament is tubular rather than flat. The student should focus first on one level, then another to study the spiral arrangement of the chloroplast. Reducing the light will enable the student to see the gelatinous sheath surrounding the cells.

The study of conjugation in *Spirogyra* is the student's first experience in observing sexual reproduction. Point out to the student that he will not be able to distinguish a plus from a minus filament on his slide unless conjugation is occurring. He will probably find several filaments with knobs forming on the cells and the cell content collected in a ball. Point out that the formation of a zygote requires that the filament conjugate with another one before the zygote is formed.

The study of *Ulothrix* introduces the student to a new kind of cell, the holdfast. He may not be able to locate holdfast cells on all of the filaments. The student should observe that the cells contain a single open-ring type of chloroplast. You may wish to discuss gamete formation in *Ulothrix* at this time.

Oedogonium is interesting to study because of the development of the large oogonial cells and the antheridial cells. The student should examine the entire slide to locate filaments containing these cells. Emphasize the fact that certain vegetative cells within the filament become modified to form these structures. A discussion of the differences between conjugation in *Spirogyra* and gamete formation in *Ulothrix* and *Oedogonium* should be introduced at this time.

Student observations—answers to questions.

- (a) Walls are thick, double and flat.
- (b) Yes.
- (c) One.
- (d) Yes.
- (e) Cells vary in length and width.
- (f) Yes.
- (g) The filament would feel slimy.
- (h) The knobs from two filaments have joined to form a conjugation tube, and the cell contents of one filament have moved into the cells of another.
- (i) Yes.
- (j) Not necessarily.
- (k) The zygote is oval and has a thick wall.
- (l) Not necessarily; the student should try to find one.
- (m) Cell is short with fingerlike projections.
- (n) Resembles an open ring.
- (o) Probably not.
- (p) Some of the cells are short; others are large and round.
- (q) Sexual reproduction involves only certain cells in *Oedogonium*. Sexual reproduction in *Spirogyra* involves all of the cells.

A Part 3 Study of Diatoms

Suggestion for procedure. Cultures of diatoms may be purchased from biological supply houses. However, they can be collected from the sides of aquaria where they form a brownish growth. The student may dissolve some silver polish or scouring powder and look for diatoms that are contained in polishing agents.

The student should examine the walls of the diatoms and note that the length of the lines varies with the species that he is examining. He will not be able to see the dots that are so close together that they appear as a single line. Point out that the resolving power of his microscope is not great enough for him to see the dots. Diatoms are

used by optical companies to determine the resolving power of the lens they manufacture. The student should examine several slides to locate the wide variety of shapes and colors found among the diatoms.

Student observations—answers to questions.

- (a) Should find yellow, golden brown, yellow green, and green.
- (b) They appear as lines.

A Part 4 Study of Marine Algae

Suggestions for procedure. Cultures of *Fucus* and *Chondrus* may be purchased from a biological supply house. If the student lives near the ocean or visits the ocean, he may collect specimens of the algae for study.

The student should examine a specimen carefully. If it is purchased in a dry form, it should be placed in a pan of water and soaked overnight to make it more pliable. The student should examine the holdfast to determine that it lacks supporting tissues found in a root. The student can observe that the bladders along the edge of the frond of *Fucus* enable the plant to float at the surface by floating it in an aquarium or pan of water. Have the student locate the receptacles on *Fucus* and point out that the life cycle of the red and brown algae is very complex and should be left for a more advanced study.

The examination and drawing of *Chondrus* is suggested so that the student may observe one type of red alga. It may be necessary to study this alga on a chart or in a text on algae.

INVESTIGATION 20-2

Diversity in Algae

Scope of the Investigation In this Investigation the student is provided an opportunity to continue his study of the algae. The collecting and identification of algae will acquaint him with a wide variety of algae differing in size, colony formation, pigmentation, types of motility and habitat (p. 277 of text).

If any student does the C-level activity, he will find that temperature plays a vital role in the growth of algae.

Approximate time required The study in Part 1 will probably extend over a period of a week, depending upon whether it is a class or special project assignment. It is interesting for the class to do the study with special students assigned to collect the samples over the weekend. To save time, several students may examine one sample; then all data can be collected and tabulated by the class. If this Part is assigned as a special project, the student should do the work after school.

Part 2 is a long-range activity and should be started at the beginning of the study on algae. Since this is an open-ended activity, the student should determine when he collects and studies the algae.

A Part 1 Collection, Examination, and Identification of Fresh-water Algae

Suggestions for procedure. Students should collect their samples from many sources, being sure to include quiet pools, drainage ditches, rapidly running water, lakes, streams, backwaters, and tributaries.

The student must keep a field notebook in which to record the collection number, place collected, depth and temperature of the water, and whether the plants were stationary or free floating. The student should also include a description of the habitat,

telling whether the water was quiet or free flowing, polluted, or fresh, and the nature of the plants and animals found there.

It will be necessary for the student to become familiar with algae keys, most of which are difficult to use. Some of the motile forms are described in keys to the protozoans. One of the easiest keys for students to use is *Algae in Water Supplies* by C. Mervin Palmer. This key may be obtained by writing the Superintendent of Documents, Washington, D.C.

All data relating to the algae samples should be recorded on the table provided. The student may require additional tables for his work.

Interpretation. Blue-green algae are found more frequently in water that is slightly polluted than in fresh water. More blue-green algae are found in drainage ditches than green. Desmids are more numerous in tributaries than in main streams. The green algae having holdfast cells are found attached to rocks in rapidly moving waters of shallow streams and along the edge of lakes where the waves break over the rocks. A pond or lake with a sandy bottom or a stream with a rocky bed yields the greatest number of diatoms.

Some algae are found in only one habitat because the environment provides all the requirements for survival.

C Part 2 Seasonal Growth of Algae

Suggestions for procedure. In selecting the pond from which he will collect his algae, the student should make sure that it will contain water for the duration of his study. The student must have a notebook in which to record all data such as temperature of water, depth from which he collected the algae, and condition of water.

The student should collect from the pond every two weeks over a period of several months, if possible. He should prepare a table of his data similar to the one in Part 1 of this Investigation.

Analysis and conclusions. In reporting his data, the student may use drawings of the algae that he found. A report should be made of all the algae showing the various stages of their development during the course of the study.

The student should account for his results in terms of the fact that many of the algae die off when the water temperature is too high and the light is too intense. Water pollution will cause some of the green algae to die off with a resultant increase in the number of blue-greens. The student will find that the formation of an ice film does not alter the populations too much.

INVESTIGATION 20-3

Lichens as Examples of the Symbiotic Relationship

Scope of the Investigation In this Investigation the student will become acquainted with various kinds of lichens. His study of the structure of the lichen introduces him to an unusual mutual relationship called symbiosis that exists between the alga and fungus plants that compose the plant body. (pp. 289-290 of the text). The concept of symbiosis will be studied in more detail in Unit 8.

His separation of the alga and fungus and the study of the effect of this isolation emphasizes the absolute dependence of the fungus member on the alga.

If a student does the C-level activity, he will find that light is required for the growth of the algal cells.

Approximate time required The student can complete Part 1 in 30 minutes. The collection of the lichen specimens for Part 2 should be done on a weekend. The actual

study of the culturing of the lichens should be done as a class project. Each specimen studied, and identified will require 30-40 minutes. Allow at least 15 minutes for the isolation and transfer of the algal cells or fungus filaments to the Petri dishes. The Petri dishes should be poured and gelled before the student comes to class. The study in Part 2 extends over a period of three weeks. This study may run concurrently with Part 3, which extends over a period of two weeks.

The preparation of the Petri dishes and inoculation in Part 3 will require 50-60 minutes. It will be necessary to do other laboratory work while this study is in progress.

A Part 1 Structure of a Lichen

Suggestions for procedure. Lichen specimens (living or preserved) may be obtained from biological supply houses. Students may collect their own specimens for study. Students will experience some difficulty with the separation of algal cells from the fungus filaments. The practice they have with the separation will help them in Parts 2 and 3 of this Investigation. The examination of the arrangement of the components in relation to each other should emphasize the fact that the fungus is parasitic upon the alga.

Student observations—answers to questions.

- (a) Answers will vary.
- (b) Probably bluish-green; they may be green.
- (c) Oval.
- (d) Greyish.
- (e) Embedded in the filaments.
- (f) No.

B Part 2 Collecting and Culturing Lichens

Suggestions for procedure. A large manila envelope may be used for holding several small sample envelopes. The student must have a field notebook in which to keep his data concerning the collection number, date, and place collected. An alga, fungus, and lichen taxonomic key will be required for identification purposes. All the data relating to the lichen should be recorded on the table provided.

The directions for the preparation of Knop's solution are provided in Investigation 21-1, Part 3. To provide the essential materials necessary for the growth of the lichen components, the student should add 2 gm granulated (not nutrient) agar to 98 ml of the Knop's solution. The medium should be brought to a boil and sufficient sterile Petri dishes for the study should be poured to a depth of 3 mm. Three dishes are required for each lichen studied. To save time, the dishes should be poured and allowed to gel before the student comes to class.

Daily observation of the specimens should show that the algal component usually continues to grow very well. However, there will be great variation in the length of time that the fungus member is able to survive. Some fungus members may live throughout the experiment since they might be able to use the substances in the medium for growth.

Student observations—answers to questions.

- (a) Lichen is growing very well; algal cells also doing well; some of the fungus filaments probably have died.
- (b) Lichen and most of the algal cells are doing well. Most of the fungus filaments have probably died.
- (c) Lichen continues to grow; some of the algal cells have probably died; none of the fungus filament seem to be alive.

- (d) The lichen and to a certain extent the algae.
- (e) The fungus.
- (f) Some of the fungus filaments probably failed to grow.

Interpretation. The lichen illustrates symbiosis in that the fungus is dependent upon the food making process of the alga. There is some evidence that the alga may be dependent upon the fungus. Thus, there is a mutual relationship demonstrated in the lichen.

C Part 3 Effect of Light on the Isolated Algal Cells, Isolated Fungus, or Entire Plant

Suggestions for procedure. The student will use the same technique for preparing Knop's solution with granulated agar that he used in Part 2. Six sterile Petri dishes should be poured to a depth of 3 mm and allowed to gel before the student comes to class. Caution the student to put the three dishes, one containing a piece of the lichen, a second with isolated algal cells and the third with fungus filaments, in the bright light so that each will receive the same amount of light, day or night. The student should examine the specimens daily noting any significant changes that occur.

Analysis and conclusions. From his study the student should conclude that the entire plant grows best in the light because the light is necessary for the alga to carry on photosynthesis. The algal cells in the light should also continue to develop and be green in color because of the presence of the light. The fungus filaments will probably die in a short time.

The algal cells soon lose their green color in the dark and will die. There will be a gradual change in the color of the lichen as the algal cells lose their color in the dark, and the plant may die before the experiment is concluded. The fungus filaments will not show much change in the dark, but they will also probably die.

Suggested References for the Teacher—Unit III

Books

- | | |
|--|---|
| <p>Alexander, M. <i>Introduction to Soil Microbiology</i>. John Wiley & Sons, New York, 1961</p> <p>Bolton, E. M. <i>Lichens for Vegetable Dyeing</i>. C. T. Bradford Co., Newton Centre, Mass, 1960</p> <p>Brock, T. D. (ed.). <i>Milestones in Microbiology</i>. Prentice-Hall, Englewood Cliffs, N.J.</p> <p>Burnet, Sir F. M. <i>Natural History of Infectious Disease</i>, 2nd ed. The Cambridge University Press, London, 1953</p> <p>Burnet, F. M. <i>Viruses and Man</i>. Penguin Books, Baltimore, 1953</p> <p>Christensen, C. M. <i>Molds and Man: an Introduction to the Fungi</i>. University of Minnesota Press, Minneapolis, 1951</p> <p>Calder, Richie. <i>Medicine and Man</i>. The New American Library of World Literature, New York, 1958</p> | <p>Calder, Richie. <i>The Wonderful World of Medicine</i>. Doubleday & Co., Garden City, N.Y., 1958</p> <p>Clifford, C. E. <i>Introduction to Bacteria</i>. McGraw-Hill Book Co., New York, 1958</p> <p>Cook, James. <i>Remedies and Rackets: The Truth about Patent Medicines Today</i>. W. W. Norton and Co., New York, 1958</p> <p>Cook, J. Gordon. <i>Virus in the Cell</i>. Dial Press, New York, 1957</p> <p>DeKruif, P. <i>Microbe Hunters</i>. Pocket Books, New York, 1926</p> <p>Dobell, C. (ed.). <i>Antony van Leeuwenhoek and His Little Animals</i>. Dover Publications, New York, 1960</p> <p>Drew, J. <i>Man, Microbe, and Malady</i>. Penguin Books, Baltimore, 1954</p> <p>Duggington, C. L. <i>The Friendly Fungi</i>. The Macmillan Company, New York, 1957</p> <p>Fox, Ruth. <i>Milestones of Medicine</i>. Random House, New York, 1950</p> |
|--|---|

- Frobisher, M. *Fundamentals of Microbiology*. 7th ed. W. B. Saunders Co, Philadelphia, 1962
- Gale, A. H. *Epidemic Diseases*. Penguin Books, Baltimore, 1959
- Garland, Joseph. *The Story of Medicine*. Houghton Mifflin Co., Boston, 1949
- Hausman, Leon. *Beginner's Guide to Fresh-Water Life*. G. P. Putnam's Sons, New York, 1949
- Hill, Ralph N. *The Doctors Who Conquered Yellow Fever*. Random House, New York, 1957
- Jahn, T. L. and F. F. Jahn. *How to Know the Protozoa*. William C. Brown Co., Dubuque, Iowa, 1950
- Kagawa, Dr. Aya. *Japanese Cookbook*. Japan Travel Bureau, Tokyo, 1957. U.S outlet: Charles E. Tuttle Co., Rutland, Vt.
- Kudo, R. *Protozoology*, 4th ed. Charles C Thomas, Publisher, Springfield, Ill., 1954
- Marriott, Henry L. *Medical Milestones*. Williams and Wilkins Co., Baltimore, Md., 1952
- Morgan, Murray. *Doctors to the World*. The Viking Press, New York, 1958
- Rahn, O. *Microbes of Merit*. The Ronald Press Co., New York, 1945
- Reinfeld, Fred. *Miracle Drugs and the New Age of Medicine*. Sterling Publishing Co., New York, 1957
- Rider, Elizabeth. *The Story Behind the Great Medical Discoveries*. Dodd, Mead and Co., New York, 1946
- Roueché, Berton. *The Incurable Wound and Further Narratives of Medical Detection*. Little, Brown and Co., Boston, 1958
- Rosenau, Milton J. *Preventive Medicine and Public Health*. 8th ed. Appleton-Century-Crofts, New York, 1956
- Shippen, Katherine. *Men of Medicine*. The Viking Press, New York, 1957
- Sutherland, Louis. *Magic Bullets*. Little, Brown and Co., Boston, 1956
- Tiffany, L. H. *Algae: The Grass of Many Waters*. 2nd ed. Charles C Thomas, Publishers, Springfield, Ill., 1958
- Articles*
- Allen, R. D., "Amoeboid Movement." *Scientific American*, February, 1962
- Andrews, Christopher H., "The Viruses of the Common Cold." *Scientific American*, December, 1960
- Bovarnick, Marianna R., "Rickettsiae." *Scientific American*, January, 1955
- Braude, A. I., "Bacterial Endotoxins." *Scientific American*, March, 1964
- Burnett, Sir Macfarlane, "The Mechanism of Immunity." *Scientific American*, January, 1961
- Fraenkel-Conrat, H. "Rebuilding a Virus." *Scientific American*, June, 1956
- Fraenkel-Conrat, Heiny, "The Genetic Code of a Virus." *Scientific American*, October, 1964
- Hotchkiss, Rollin D. and Weiss, Esther. "Transformed Bacteria." *Scientific American*, November, 1956
- Lamb, I. M. "Lichens." *Scientific American*, October, 1959
- Langer, William L., "The Black Death." *Scientific American*, February, 1964
- Lee, John J., and Freundenthal, Hugo. "Tiny Drifters of the Sea." *Natural History*, October, 1964
- Mudd, Stuart, "The Staphylococcus Problem." *Scientific American*, January, 1959
- Nossal, G. J. V., "How Cells Make Antibodies." *Scientific American*, December, 1964
- Rose, Anthony H., "New Penicillins." *Scientific American*, March, 1961
- Rubin, Harry, "A Defective Cancer Virus." *Scientific American*, June, 1964
- Speirs, Robert S., "How Cells Attack Antigens." *Scientific American*, February, 1964
- Spiegelman, S., "Hybrid Nucleic Acids." *Scientific American*, May, 1964
- Stent, G. S., "Multiplication of Bacterial Viruses." *Scientific American*, May, 1953
- Trexler, P. C., "Germ-Free Isolators." *Scientific American*, July, 1964
- Weiss, Francis J., "The Useful Algae." *Scientific American*, December, 1952
- Wollman, Elie, and François Jacob, "Sexuality in Bacteria." *Scientific American*, July, 1956
- Yoeli, Meir, "Animal Infections and Human Disease." *Scientific American*, May, 1960

UNIT FOUR

MULTICELLULAR PLANTS

This unit covers the morphology of the two large groups into which the plant kingdom is frequently divided—Bryophyta and Tracheophyta. The presence of vascular tissue separates the tracheophytes from bryophytes.

Through the marvelous chemical activities of green plants, organic compounds essential to other organisms are organized, with common inorganic substances serving as raw materials. Thus, the green plant is a chemical necessity for life as we know it. We live in the age of seed plants. This unit will explain why these plants have become the supreme form of plant life on the earth today.

Excellent class discussions should grow out of the study of this unit. Students usually have had a wide experience with seed plants and can draw on this practical background. The abundance of materials available should provide a variety of laboratory and project experiences. Knowledge of this unit will provide an essential background for the study of other groups of living things. Practical applications of the unit apply to the many plant industries, to beautification through the use of plants, to field observations, and to plant-growing hobbies.

OUTCOMES

The study of this unit should result in:

1. Understanding of the place of mosses and ferns and their relatives in the plant kingdom.
2. Familiarity with the reproductive cycles of various plants.
3. Ability to recognize the relationship of mosses and ferns and their relatives to one another and to the complex seed plants.
4. An awareness that plant populations have changed during the history of the earth.
5. Understanding of the place of seed plants in the plant kingdom and the complexity and efficiency of their tissues and organs.
6. Understanding of the structure and functions of roots, stems, and leaves and adaptations of these vegetative organs for specialized functions.
7. Knowledge of the processes of a plant, including absorption through the forces of imbibition and osmosis, the forces involved in conduction, photosynthesis, transpiration, and other processes centered in leaves.
8. Understanding of vegetative propagation of plants by cuttings, budding, and grafting.
9. Knowledge of the make-up of a flower and the reproductive process.
10. Acquaintance with fruits and seeds and the ways in which plants travel in these stages.
11. Understanding of seed germination and the conditions required for germination.
12. Awareness of problems relating to plant growth and reasons for distribution of plants in different environments.
13. Appreciation of the seed plant as a functioning unit, performing many related and unrelated processes simultaneously and efficiently because of its many specialized tissues.

Chapter 21

Mosses and Ferns

Although most high school students have seen moss growing in cracks of steps or sidewalks or on shady banks, the actual observation of a single moss plant with a hand lens will often be a new experience. The parasitic sporophyte growing from the gametophyte may be more closely examined with the microscope. Covered aquaria, terraria, or gallon jars provide a favorable moist environment in which the bryophytes may live. It is suggested, therefore, that the teacher begin collecting samples of the bryophytes several weeks in advance of the study.

Some teachers have had success with growing fern prothalli on inverted flowerpots kept damp and covered with a large beaker. If this is planned, the fern spores should be dusted on the flowerpot at least four weeks prior to their need.

In teaching this chapter, several economic values of the mosses and ferns should be stressed. Include the value of the moss as a pioneer plant, and its role in soil formation on rock and barren soil, as well as uses of sphagnum moss and peat. The age of pteridophytes and coal formation are interesting topics for special reports. Cross-section slices of the stem of a fern frond readily show the vessels.

P. 296, Fig. 21-3: Use open books to go over this diagram and make clear alternation of generations. Use collected specimens. Some, like the hairy cap or pigeon wheat moss of the eastern United States, can be dried and used more than once.

P. 297, left column: Peat is still used as fuel in some parts of the world. In World War I, sphagnum was used as a wound dressing because of its antiseptic acidity and absorbency. Log moss is used by florists to line hanging wire baskets so that they will hold soil.

P. 298, Fig. 21-6: Discuss the Carboniferous period and examples of plants left today in tropical rain forests like El Yunque in Puerto Rico.

P. 299, Fig. 21-7: Use for open-book discussion and alternation of generations.

P. 301, right column: Report on how

fossils are formed and show specimens if possible. Stress the conservation angle of Fig 21-9.

Suggested Films

Early Land Plants (col, 28 min) AIBS McGraw-Hill

Evolution of Vascular Plants—The Ferns (b&w&col, 17 min) EBF

Ferns and Their Allies (col, 28 min) AIBS McGraw-Hill

The Bryophytes (col, 28 min) AIBS McGraw-Hill

MAJOR CONCEPTS

1. The mosses and ferns are comparatively simple land plants.
2. The mosses and liverworts thrive in moist terrestrial habitats, but some even live in hot springs.
3. The mosses and liverworts may have been the first plants to live exclusively on land.
4. Bryophytes do not have efficient water-conducting tissues, or true roots, and are therefore restricted to moist environments.
5. Bryophytes have a more complicated reproductive cycle than the algae.
6. The mosses and liverworts like the algae, show alternation of generations.
7. Mosses are important as pioneer plants in rocky areas.
8. The absorbent quality of sphagnum makes it valuable to the gardener as a mulch.
9. The ferns and their relatives once occurred in forests which formed deep layers of organic material. Movements of the earth compressed these layers into coal.
10. The familiar fern is the sporophyte generation in the life cycle.
11. The fern is considered a tracheophyte because it has conducting vessels.
12. The horsetail rushes and the club mosses are relatives of ferns.
13. The bryophytes and the ferns are dependent on water through which the sperm must travel to fertilize the egg.

ANSWERS TO QUESTIONS FOR REVIEW (Page 302)

1. Water moves from cell to cell through the stem of the leafy shoot of a moss. Mosses lack the vascular tissues of the ferns and seed plants. Thus the distance water can move upward is limited and this limitation prevents the moss from becoming tall.
2. The gametophyte phase of a moss consists of the leafy shoot, on which antheridia and archegonia are produced. The sporophyte phase grows on the gametophyte and consists of a stalk and capsule.
3. Fertilization, or union of the male and female gamete.
4. Floating mats of sphagnum moss grow in lakes, usually near the edges at first. Season after season, new plants replace older ones on the surface of the mat. The remains of dead plants decompose in the mat and become peat. Over a period of hundreds of years this activity changes a lake into a bog.
5. Mosses are important in soil formation on rocks and in barren regions. Sphagnum moss is widely used in packing nursery stock and as a mulch in gardening.
6. Coal formation began in marshy regions with the accumulation of plants, mostly ferns and fern allies, in past geological ages. As slow decomposition of the plant remains occurred, carbon was left. These plants were buried and compressed by internal pressure in the earth into what we now mine as coal.
7. The familiar fern frond grows from a fiddlehead produced on the underground stem, or rhizome. The frond bears clusters or sporangia in sori, or fruit dots, on the underside of the leaves. The spores escape and grow into a filamentous prothallus, the first gametophyte stage. This develops into the heart-shaped prothallus, with archegonia and antheridia. Sperm and egg unite in an archegonium and form

the zygote, which grows into a new sporophyte plant.

8. Spores develop in helmet-shaped sporangia, attached to the frond in the sori.
9. The young sporophyte generation of the fern grows from the archegonium on the lower side of the prothallus. A foot of the sporophyte absorbs nourishment at first, but soon develops its own roots, rhizome, and leaves and becomes an independent plant.

ANSWERS TO APPLYING PRINCIPLES AND CONCEPTS (Page 302)

1. In some plants, only one of the eggs receives a sperm. In others, the first zygote formed has the advantage of anchoring into the tissues of the leafy shoot and absorbing nourishment.
2. During the Carboniferous period, much of the earth was marshy and not a suitable environment for the seed plants as we know them today. As the earth changed in later periods and land masses were elevated, conditions became ideal for seed plants. They gradually crowded out the remaining pteridophytes.
3. The sporophyte plant of a moss is the stalk and capsule which lives as a parasite on the gametophyte leafy shoot. The leafy shoot is the more advanced of the two. The sporophyte of a fern is the conspicuous generation, with roots, stem, and leaf. The gametophyte is the inconspicuous prothallus.
4. The roots of a fern are far more efficient absorbing organs than the rhizoids of a moss leafy shoot. Furthermore, the fern roots contain vascular tissues like those of the seed plants and can conduct water a much greater distance. This advantage permits much larger leaves, and tall upright stems in the case of tree ferns.

Guide to Laboratory Investigations for Chapter 21

INVESTIGATION 21-1

The Mosses

Scope of the Investigation This Investigation exposes the student to one of the most widespread but least recognized groups of plants. He may observe the structures that enable the mosses to make the transition from water to land life, as he studied on p. 294 of the text. The concept of alternation of generations discussed on p. 296 is further defined by a study of the life cycle of the moss. Extensive study of the morphology of the moss exposes the student to multicellular sex organs (p. 295). If any student pursues the C-level Part, he will gain further awareness of moss structure, experience in the field, and experience in using taxonomic keys.

Approximate time required If all observations and drawings in Part 1 are included, the average student should be able to complete the work in three 50–60 minute periods.

Part 2 should require approximately 30 minutes.

Part 3 will require at least two weeks, because of the time that must be allowed for germination and growth. However, this Part 3 may be correlated with other laboratory activities.

Part 4 is a long-range project for the student interested in pursuing his study of the mosses further.

A Part 1 Study of Moss Gametophyte and Sporophyte Plants

Suggestions for procedure. Effective examination of the reproductive structures of the moss will require living specimens. Preparation of the archegonia and antheridia is rather difficult, and may be omitted.

Student observations—answers to questions.

- (a) Yes.
- (b) No.
- (c) Yellowish, brownish, or colorless.
- (d) The protonema stage resembles the structure of a filamentous alga.
- (e) They are arranged in whorls around a central axis.
- (f) They are in a flat sheet, and adjacent cells are distinct.
- (g) It is one cell thick except along the midrib.
- (h) Around the edge of the cell.
- (i) No.
- (j) Streaming may be found in some cells.
- (k) They probably will be found.
- (l) Sperm have two cilia.
- (m) Only certain leafy shoots bear archegonia.
- (n) Won't always be present.
- (o) Usually, but not always.

A Part 2 Life Cycle of a Moss

Suggestions for procedure. Since the study of an entire life cycle as it occurs in nature would be difficult to undertake in the classroom, the life cycle diagram is provided for the student. He should first study the diagram carefully and identify the structures. Then he should determine whether the structures are n or $2n$.

Student observations—answers to questions.

- (a) Spore.
- (b) It resembles a filamentous alga.
- (c) To provide a medium for the motile sperm.
- (d) The sporophyte lacks chlorophyll-bearing cells.
- (e) A haploid (n) gametophyte generation gives rise to a diploid ($2n$) sporophyte generation.
- (f) In production of spores.
- (g) In fertilization and the formation of a zygote.

B Part 3 Growing Moss Protonema

Suggestions for procedure. A hot-air oven suitable for sterilizing glassware is necessary for this Investigation. Also necessary is the special medium, which can be prepared and stored prior to undertaking the Investigation. Students growing moss protonema should prepare their own medium according to the instructions in their manual. It is essential that granulated agar and not nutrient agar be used. In placing the spores on the surface of the agar, care must be used to distribute them thinly and evenly, and to avoid contamination. Students should be cautioned to sterilize the forceps with alcohol rather than a flame.

Student observations—answers to questions.

- (a) The bud shows evidence of tissues formed by the leafy gametophyte that are not present in a protonema.

Interpretation. Cells of the bud are more specialized than cells of the protonema. Each protonema produces a gametophyte characteristic of the species.

C Part 4 Field Study of Bryophytes

Suggestions for procedure. Part 4 requires a great deal of time and effort. If, before making any attempt to identify the specimens, the student acquaints himself thoroughly with the terms used to describe structures in the taxonomic keys, time and errors will be reduced. If the student would note other plants growing in the area of each of the specimens, he could gain insight into some ecological relationships.

Analysis and conclusions. The student may present his materials in a variety of ways, but the use of photographs and drawings is very important in this study. The student should show the important characteristics that are used for identification. Also, descriptions of the habitats of the various species are important, for in spite of their simple structure, mosses can live in many areas that will not support the growth of higher plants.

INVESTIGATION 21-2**The Ferns**

Scope of the Investigation In this Investigation the student becomes familiar with the large independent sporophyte as the dominant generation in the ferns, and sees the trend toward the small, dependent gametophyte, which he has studied on pp. 299-300 of the text. He observes, for the first time, plants with specialized organs and conducting tissues (p. 299). He sees that water is still required for fertilization in the ferns (p. 300), indicating that the transition to life on land is still not perfected. The

student can compare the growth of the young fern gametophyte to the filamentous algae and the protonema of the moss, an idea he met on p. 300 of the text. If a student undertakes the C-level Part, he will gain further experience with the structure of various fern species as well as experience with taxonomic keys. He should become aware of the structural advances of the ferns over the mosses and the limitations that cause the ferns to be unable to compete with the flowering plants.

Approximate time required. The average student should be able to complete all activities of Part 1 in two 50–60 minute periods.

Part 2 should require 50–60 minutes if all activities are included. If living prothalli are not available, this section can be omitted, and Part 2 should then require 20–30 minutes.

Part 3 should require approximately 30 minutes.

Part 4 is a project that could take up to three months if the prothalli are to grow to maturity.

Part 5 is a long-term project for the student who is interested in further study of the morphology and taxonomy of the ferns.

A Part 1 Study of the Sporophyte Fern Plant

Suggestions for procedure. If students are to examine living sporangia discharging spores, it will be necessary to provide them with glycerin and/or gooseneck lamps. Students should be cautioned to place the glycerin on the slide touching the edge of the cover glass, taking care not to get it on top of the cover glass. If prepared slides of a fern rhizome are not available, the student may use a razor blade or very sharp scalpel to cut a thin cross section of the rhizome and prepare it as a wet mount, using a simple stain such as methylene blue.

Student observations—answers to questions.

- (a) It is large, has vascular tissues, and lives independent of the gametophyte.
- (b) Along the annulus.
- (c) The thin outer wall is drawn in, pulling the radial walls of the annulus cells together and bending the annulus backward.
- (d) It plasmolyzed the cells, thus reducing the osmotic pressure. This released the tension on the thick walls, causing them to spring inward.
- (e) Water loss from cells during a dry period.
- (f) Answers will vary with different fern species. Commonly, the xylem lies in a single central rod surrounded by phloem.

A Part 2 Study of the Fern Gametophyte Plant

Suggestions for procedure. Since living prothalli may be difficult to obtain, prepared slides can be used for the major part of this study. If living prothalli are used, students should be cautioned to use only low power on the wet mount of the entire structure to avoid crushing it.

Student observations—answers to questions.

- (a) They lack vascular tissues and are unbranched.
- (b) It swims in a film of water on the lower side of the prothallus.
- (c) No. They lack both absorbing and water-retaining cells and therefore are easily killed by drying.
- (d) Cell division occurs only at the apex of the prothallus; also, the prothallus lacks tissue for conducting and storing water.
- (e) It is one cell thick except below the sinus, where it is several layers thick.
- (f) They are spirally coiled and bear many flagella.
- (g) Probably.

A Part 3 Life Cycle of a Fern

Suggestions for procedure. Since the complete life cycle of the fern is difficult to observe in nature, a diagram of the cycle is provided for the student. He should first study the diagram and identify all of the structures. Then he should determine whether each structure is n or $2n$.

Student observations—answers to questions.

- (a) In the production of spores.
- (b) In the fertilization of the egg in the archegonium.
- (c) The prothallus.

B Part 4 Growing Fern Prothalli

Suggestions for procedure. For this Investigation, a hot-air oven suitable for heating soil is required. Either humus or rich loam may be used for the substratum. A bell jar that fits over a 4–5 in. flowerpot saucer is necessary to create a moist chamber. Students should be cautioned to place the apparatus in reduced light, and to keep the humus moist, but not wet. Many students have a tendency to over-water the soil.

Interpretation. The young prothallus is filamentous and resembles both filamentous algae and the moss protonema.

C Part 5 Field Study of Ferns

Suggestions for procedure. Part 5 will require extensive field work and use of taxonomic keys. Students should be encouraged to familiarize themselves with the structural characteristics used in classifying ferns before they attempt to identify any specimens, and preferably before they begin collecting. It is important that fertile fronds be included in the collection, as the arrangement and structure of the sori and sporangia are valuable taxonomic aids. A large book or magazine is useful for holding specimens in the field and while identifying them. However, the student should be encouraged to press, dry, and mount them neatly, recording pertinent information, thus beginning his own herbarium.

Analysis and conclusions. As in the field study of the mosses, photographs and drawings and descriptions of characteristics and habitats should be included. The study should result in an understanding that, while ferns as a group are an advanced kind of plant with vascular tissues and are able to live on land, they depend on water as a medium in which their motile sperm reach the egg.

Chapter 22

The Seed Plants

We begin the study of seed plants with a survey of gymnosperms and angiosperms as the two great classes. The plant body of a flowering plant is discussed to give the student an idea of the plant as a whole before he studies its individual organs in greater detail.

An ideal introduction to the seed plants is to study the seed as an embryo plant

supplied with food and capable of lying dormant and being carried to a distant place. Some teachers prefer the study of seeds at this point in the course. If so, Chapter 26 could follow the introductory chapter.

The importance of conifers in forestry and in yard planting should be discussed. Families of conifers and of monocots and

dicots are listed in tables as a general survey. In the introductory study of the plant body, the authors suggest that you stress the specialized functions of each organ. This approach gives the student an understanding of the plant as a whole and the interrelation of its parts.

Collections of seeds, plants, or plant parts increase a student's understanding of the diversity among the plants. As a special project, students may wish to germinate and preserve many seeds of monocots and dicots.

P. 304, right column: Obtain ginkgo leaves if possible. They show dichotomous veining in which the veins radiate like a fan from a central point. The male and female trees are separate and the fruit is rather smelly and messy when it drops to the ground.

P. 306, Fig. 2-4: Discuss the advantages of leaves that are small needles or scales, the presence of a thick cuticle, and how these traits relate to the environment.

P. 308 and 309, tables: Have students make charts with drawings or dried specimens. Use local material where possible. A well-planned lesson could be prepared with specimens from the grocery and other sources of commercially important plants. If enough samples are brought to class, each member can have one to touch, smell, draw, or eat (where feasible). The following are suggested to introduce students to familiar and not so familiar plants:

1. Peanut—sketch and take apart. Label seed coat, cotyledons, embryo.
2. Sunflower seeds—sketch external and internal views. Large salted seeds from Mexico may be bought in jars.
3. Cloves—sketch the dried flowers.
4. Nutmeg and mace—explain the relationship between these two and have students sketch. Nutmeg is used by some people for “kicks.” In large quantities it is harmful.
5. Cinnamon—whole and ground could be used. This bark is sometimes adulterated with pecan shells.
6. Nuts—study different kinds, as some students are not familiar with them: pecan, walnut, hazelnut, brazil, and almond.

7. Poppy seeds—explain the difference between these and the opium poppy.
8. Sesame seeds—these are used on bread and cakes. They are an important food in the Orient where they provide oil.
9. Anise seeds—these are used in and on Italian cookies and in some liqueurs. The taste is like licorice.
10. Tea—green and black. Examples of the leaves can be used.
11. Coconut—have a whole fresh one for sketching and small pieces for consumption. The embryo can be found near one of the “eyes” and is very small.
12. Vanilla bean—the fruit of an orchid. The process of making vanilla extract is an interesting topic for a report.
13. Indian nuts—the seed of the piñon pine is gathered by the Indians, and is an important cash crop for them. Refer to Fig. 22-2, p. 304 to show how the seeds look in the cone.
14. Mint—this can be obtained dry when it is sold for making mint tea or fresh from the garden.

Other plants may be used. A map could be made showing where these foods are obtained in the world. A chart could be made of other plant fibers and their sources: linen, jute, sisal, cotton, rayon, and others. In the bibliography at the end of this unit are included appropriate references.

P. 311, left column: *Digitalis* is an important heart drug. Its source and use would be interesting information for the class.

Suggested Films

Gymnosperms (col, 28 min) AIBS McGraw-Hill

Likeness and Differences in Angiosperms (col, 28 min) AIBS McGraw-Hill

Seed Germination (b&w&col, 15 min) EBF

MAJOR CONCEPTS

1. The seed plants have well-developed water-conducting vessels, true roots, and leaves.

2. Water is not required for fertilization. Therefore, these plants are not restricted to moist environments.
3. The development of the seed, with its protection of the young sporophyte generation, has been of vital importance in the evolution of this group.
4. The presence or absence of a fruit enclosing the seed is the basis for the division into the classes Gymnospermae and Angiospermae.
5. Plants spread to new locations by means of seeds.
6. Of all the gymnosperms that ever existed, the conifers are the best suited to present world conditions.
7. The presence of either one or two cotyledons divides the angiosperms into two subclasses: Monocotyledoneae and Dicotyledoneae.
8. Each organ of a flowering plant is highly developed for performing certain activities.
9. The various organs of a seed plant are composed of specialized tissues.

for absorption, anchorage, conduction, and storage; the stem, for display of the leaves, conduction, storage, and food manufacture; the leaf, for food manufacture, transpiration, and respiration.

6. Epidermis, cork parenchyma, xylem, phloem, and meristematic tissue.
7. Herbaceous plants have soft stems containing a large amount of parenchyma tissue and little woody tissue and last, usually, a single growing season. Woody plants have stems with a large amount of woody tissue, usually increased each year by activity of the cambium. Woody plants include trees, shrubs, and many vines. Herbaceous plants are represented by the tomato, bean, pea, and zinnia.
8. The annual grows from a seed, flowers, and produces in a single growing season. The biennial usually forms the vegetative growth the first season and flowers and bears fruit the second season. The perennial grows and reproduces season after season (more than two seasons).

ANSWERS TO QUESTIONS FOR REVIEW (Page 312)

1. Gymnosperms do not produce flowers and have naked seeds. Angiosperms are flowering plants and bear seeds enclosed in an ovary, which develops from the pistil of the flower.
2. The ginkgo tree is the sole survivor of an entire order of gymnosperms, the Ginkgoales, which flourished ages ago.
3. We use conifers, including the yew, hemlock, white cedar, and red cedar in foundation plantings. Pines, spruces, firs, and other conifers are planted as specimen trees, screens, and windbreaks.
4. Answers to this question will vary but may include as monocot families: grass, lily, amaryllis, iris, and orchis; as dicot families: crowfoot, poppy, rose, pulse (legume), parsley.
5. The vegetative organs of a seed plant and their functions include: the root,

ANSWERS TO APPLYING PRINCIPLES AND CONCEPTS (Page 312)

1. One major reason for the disappearance of many gymnosperms was the invasion of gymnosperm forests by the angiosperms. Angiosperms can grow in deeper shade (many forest species) than gymnosperms, especially conifers. Most coniferous forests are found, today, in areas of poor soil where they escape crowding out by angiosperm trees.
2. High development of roots allows absorption from a greater area and greater depth, storage of food and water, and anchorage of a large stem. The stem is highly developed for support of a large crown of leaves and the conduction necessary to support such a leaf area. Leaves are ideally suited to absorption of light during

food making, transpiration, respiration, and their other normal functions.

3. Since annuals are started from seeds or from young plants, an entire bed can be prepared at once. There is not

the problem of wintering over. Since blooming occurs at the maturity of the plant, there is, usually, a large display of blossoms. The energy of the plant is directed into flower and seed production.

Chapter 23

Root Structure and Function

A study of the plant body could start with any of the vegetative organs. The authors selected the root because it serves as the organ of supply to the other organs through its contact with the soil. The root is a basic necessity to all plant functions. The logical place to start the study of roots is with the growth of the primary root from the seed. With the maturation of the primary root tissues and the growth of the root system as branch roots develop, the story of roots unfolds.

Root responses are excellent examples of tropisms. Since a young root responds rapidly, it is an ideal subject for demonstrating these responses. You will probably wish to discuss tropisms in detail in connection with this chapter. Modification of roots and the many functions of specialized roots is an excellent lesson in adaptation. A survey of root crops sold in grocery stores is an interesting and practical study.

Activities of this chapter should include the examination of the roots of many plants which the students can bring in. Freshly germinated seeds may be used to demonstrate root hairs. Commercially prepared cross sections of monocot and dicot roots show interesting differences. Carrots, turnips, and beets may be used for observation, drawing, and identification of the structures. Prepared slides of root tips also may be used to present an understanding of root growth.

P. 313, right column: Fibrous roots are important to desert plants and in many species branch out from the plant near the soil surface to get any available moisture. When the rain does fall, the desert suddenly bursts into bloom.

P. 315, Fig 23-4: Radishes germinate quickly if placed in a Petri dish with a damp blotter. It is easy to see the root hairs.

P. 321, Fig 23-11: This type of plant activity makes it difficult for the archeologist studying ancient buildings that are overrun or destroyed by rapid jungle growth. In Ankor Wat, in Cambodia, the famous "cheese trees" engulf and split the buildings and the jungle growth must be constantly trimmed.

Suggested Films

Plant Tropism and Other Movements (b&w&col, 11 min) Cor
Roots (col, 28 min) AIBS McGraw-Hill

MAJOR CONCEPTS

1. An average land plant has about as much or more below ground as above ground.
2. Generally, the roots of plants serve in anchorage and food storage as well as to absorb water and minerals from the soil.
3. Roots may be classified according to their branching and specialized functions.
4. Roots grow in length by means of rapidly dividing cells at the tips.
5. Carbon dioxide given off by the cells at the tip of the root forms carbonic acid when combined with soil water. This helps dissolve certain minerals in its path.
6. A layer of dividing cells called the vascular cambium increases the diameter of the root.
7. The roots of many plants serve as organs of reproduction.
8. Successive osmosis and turgor pressure aid in carrying water and minerals to the stem.
9. Root cells selectively absorb and concentrate certain mineral ions.
10. External stimuli result in growth responses which can be observed and measured.

ANSWERS TO QUESTIONS FOR REVIEW (Page 324)

1. A primary root develops from the embryo present in the seed. The secondary root grows from the pericycle of the primary root.
2. The taproot system centers around a greatly enlarged primary root. The diffuse root system is composed of many secondary roots which spread over a large area. There is no main primary root. In most plants, the primary root ceases to grow after it forms the secondary roots.
3. Carbonic acid dissolves minerals in the soil and aids the forward progress of the root.
4. Root cap, meristematic region, elongation region, and maturation region in the order named are from the tip back. The root cap is a protective structure. The meristematic region gives rise to new cells by continuous divisions during the growing season. Cells, formed in the meristematic region, grow in length in the elongation region. In the maturation region, the cells mature into tissues, such as the epidermis and cortex.
5. A root hair is merely an extension of a single epidermal cell. A branch root is an entire root, containing root tissues.
6. a. Epidermis (absorption and protection); b. cortex (storage); c. endodermis (a boundary layer between the cortex and the central cylinder); d. pericycle (origin of secondary roots); e. phloem (food conduction); f. cambium (production of secondary tissues); g. xylem (conduction of water and minerals).
7. Normal roots grow from the base of a stem, or from another root. Roots that grow from the nodes of a stem, from leaves, or from places other than normal locations, are classed as adventitious.
8. Adventitious roots serve as braces (corn), for climbing (ivy), and for propagation (raspberry).
9. When the epidermal cell takes in water, the concentration of water

molecules becomes greater than that of the cortex cell lying against it, so that water passes from the epidermal cell to the cortex cell. As the water in this cell increases, the next cortex cell receives water from the first. This diffusion of water from cell to cell is called successive osmosis.

10. The responses of various plant parts to stimuli of the environment are called tropisms and may be positive or negative. Roots show a positive response to gravity and to water. Root responses are related to hormone secretion.

ANSWERS TO APPLYING PRINCIPLES AND CONCEPTS (Page 324)

1. Hickory trees thrive on dry ridges because they have extremely long taproots, permitting absorption of water from deep supplies during dry seasons.
2. When small roots bearing root hairs are exposed to the air, they shrivel and die. Thus a plant that is dug up with its roots exposed must survive until new young roots can grow and begin absorption of water and minerals.
3. The cambium produces secondary xylem cells on its inner side and secondary phloem cells on its outer side by continuous division during the growing season.
4. The branch root must be joined to the conducting tissues of the central cylinder of the root that produced it. Otherwise it could not receive food from the plant, nor could it supply water and minerals.
5. Hydrotropism is the response that directs the growth of a young root to water. Undirected growth of roots would probably fail to provide sufficient water to supply the plant.
6. Radioactive isotopes have been used to study the uptake of various minerals by roots of plants. In one experiment two plants were watered, one with distilled water and one with water containing radioactive phos-

phate. In 45 minutes, the water containing the radioactive phosphate was absorbed through the root hairs and had moved up to the leaves. The

leaves of the plant watered with distilled water only showed no such radioactivity. Neither plant showed radioactivity before the experiment.

Guide to Laboratory Investigations for Chapter 23

INVESTIGATION 23-1

Root Structure

Scope of the Investigation This Investigation gives the student the opportunity to observe the structure of specialized tissues of a mature root, which he has studied on pp. 315-317 of the text. He also is required to give further attention to the special activities of each of the root tissues. The student observes, in the carrot, secondary growth as a result of the activity of cambiums (lateral meristems), which he has studied in the text on pp. 316-317.

Approximate time required Neatness and accuracy are essential in Part 1, but the average student should be able to complete it within a 50 minute period.

Part 2 should be completed by the average student in approximately 35 minutes.

A Part 1 Primary Tissues of a Mature Root

Suggestions for procedure. Students should be provided with prepared slides showing a cross section of a mature root. Buttercup (*Ranunculus*) that has been differentially stained is excellent for this study. The student should study the entire section under low power first, taking time to identify all of the tissues before switching to high power for detailed cellular study. The drawing may be made in hard lead or colored drawing pencils (with a color key to the tissues), but cellular detail should be shown.

Student observations—answers to questions.

- (a) One or two.
- (b) Variable.
- (c) Usually.
- (d) Usually one cell.
- (e) Xylem and phloem.
- (f) Lies in a narrow band between the xylem and phloem.

A Part 2 Regions of a Mature Root (Carrot)

Suggestions for procedure. For this study fresh carrots should be selected that have as many secondary roots present as possible. Carrots carefully dug by hand for this study would be ideal. Two students can work together on this study, one making the longitudinal section of his carrot and the other making the cross section. Students should be cautioned to cut the carrot carefully, and to make the longitudinal section the entire length of the carrot.

Student observations—answers to questions.

- 1. Growth
- 2. Protection, absorption of water and minerals
- 3. Storage of food and water
- 4. No special function known

5. Origin of secondary roots
6. Conduction of food downward
7. Production of secondary xylem and phloem
8. Conduction of water and minerals upward

INVESTIGATION 23-2

Absorption of Roots

Scope of the Investigation This Investigation demonstrates the passage of water through the root, a process which the student has studied on pp. 320-321 of the text. It is designed to give the student a better understanding of the direction of water movement as determined by various concentrations of substances inside and outside of the root cells, which he has studied both on p. 320 of the text and previously on pp. 73-77. The student observes the effects of concentrated solutions on roots and other plant organs, and is given visual evidence of the way in which excessive applications of soil minerals or fertilizers can damage roots (p. 320 and pp. 76-77). If the student chooses to undertake Part C, he provides himself with evidence of the absorption and translocation of soil minerals that he has studied on pp. 321-322 of the text, and gains experience in working with radioisotopes.

Approximate time required The basic experiment for Part 1 can be set up by the average student within a 50-60 minute period. On each of several following days, an observation and recording period of 5 minutes will be required, and 15 minutes to dismantle the apparatus on the final day.

Part 2 can be set up, and the first observation made, in a 50-60 minute period. An additional 20-30 minutes will be required 24 hours later to make a second observation, record data, and dismantle the apparatus.

Part 3 is an individual project which will require at least two hours on each of several days.

A Part 1 Absorption of Water by a Root

Suggestions for procedure. In addition to the standard laboratory apparatus, students should be provided with a carrot, a cork borer or small vegetable corer, dark molasses syrup, and paraffin. Students should be cautioned when inserting the glass tubing into the rubber stopper. Both should be wet, and the tube should be grasped very close to the end being placed into the stopper. The tube should be inserted carefully with a twisting motion; it should never be forced. If it does not enter the stopper, both should be moistened again. The core removed from the carrot should be as deep as possible, taken from the center, and about one-half inch in diameter. The opening at the top should be smooth and even, with no cracks to the outside of the carrot. The stopper and tube should be inserted firmly, but not so far as to split the carrot. Students should be urged to exercise *extreme* caution in melting and handling paraffin. When marking the level of the molasses on the tube, care should be taken not to dislodge the tube or break the paraffin seal.

Student observations—answers to questions.

- (a) Answers will vary.
- (b) Answers will vary.
- (c) Answers will vary. It reached its highest level when the pressure of the weight of the solution in the carrot and tube was equal to the diffusion pressure of the water in the jar.

- (d) The movement of water molecules was from the region of greater concentration, through the carrot tissues, to the area of lesser concentration in the center of the carrot.
- (e) The molasses is a concentrated sugar solution. When it is put into the core of the carrot, the principle of osmosis can be demonstrated.
- (f) Water molecules were less concentrated in the molasses and the water molecules in the jar diffused through the carrot tissue, which is permeable to them.
- (g) The pressure within the carrot became as great as the diffusion pressure that caused the water molecules to move inward. An equilibrium was established and diffusion stopped.

B Part 2 Effect of Salt Solutions on Osmosis in Roots

Suggestions for procedure. Coleus plants are suggested for Part 2. However, another small, healthy variety of plant can be substituted, such as 5-6 in. bean seedlings. Students should prepare their own solutions, and should be certain that all solutions are in the flasks and the flasks marked *before* they remove the plants from the soil. Thus they will avoid wilting not directly related to the salt solutions. Care should be exercised in removing the soil from the roots to avoid injury to the small roots and delicate root hairs.

Interpretation. Answers will vary. However, a 10.0% NaCl solution should cause a rapid wilting of the roots. The 0.1% and 0.5% probably will have little effect on the plant tissues because the concentration is not sufficient to cause plasmolysis.

C Part 3 Absorption and Translocation of Radioactive Phosphorus (P^{32}) in Tomato Plants

Suggestions for procedure. In addition to regular laboratory materials, the student who undertakes Part 3 should be supplied with two 5-6 in. tomato plants, Saran Wrap, radioactive phosphorus (P^{32}), a Geiger counter, a lead plate, glossy high-contrast paper, X-ray film and a developer. Extreme caution should be exercised when working with radioactive materials. It is essential to emphasize at this point that this experiment should not be undertaken by any student unless he can be under the constant supervision of someone who has completed a course in radiation biology and is thus familiar with the techniques for handling radioisotopes. The 10 μ c of P^{32} can be secured in kits with other radioisotopes. It may be wise to purchase the P^{32} independently of other isotopes, however, unless they are to be used in a short time because they have short half-lives. The student should be familiar with the Geiger counter and its use before undertaking this study. In working with the Geiger counter, the student should be sure to measure the background radiation, and to subtract that from his later counts. When working with P^{32} the student should wear rubber gloves, cover the work table with paper and thoroughly wash all utensils used in the study. In making the radioautograph, X-ray film should be used, and the radioautograph should not be attempted unless the student gets a count of over 5,000 counts per minute.

INVESTIGATION 23-3

Phototropism and Geotropism in Plants

Scope of the investigation This Investigation gives the student an opportunity to study the involuntary growth responses to various stimuli, as discussed on pp. 322-323 of the text. He will see the behavior of stems, roots, and leaves in response to light (p. 322) and gravity (p. 323). This Investigation should aid the student in dispelling any

ideas he may have that plants grow in a particular way by chance, in response to a need, or due to some internal will.

Approximate time required Part 1 will require approximately 10 minutes to plant the seeds, and a few minutes of daily care until they reach a height of three inches. Approximately 30 minutes should be required to set up the boxes and other apparatus. For three to four weeks, 5 minutes daily will be required for care, observations, and recording.

Part 2 will require 30 minutes to set up the first experiment, using plants grown previously. Five minutes of observation will be required daily for one week, and 30 minutes for the final observation. The second experiment in Part 2 will require approximately 20 minutes to set up, and 5 minutes of daily observation for one week. The third experiment should require a period of 50-60 minutes to set up, and three days to rotate the turntable.

B Part 1 Phototropism

Suggestions for procedure. Two experiments illustrate phototropism in Part 1. Students should grow several bean seeds in moist vermiculite. Three healthy seedlings will need to be potted for each section of Part 1. Students should be sure that the plants in the boxes do not touch the sides or tops of the boxes, and that light enters the boxes only through the holes cut expressly for that purpose. All boxes should be set in the same area, receiving the same amount of light. Care should be taken that one box does not cast a shadow on another, or otherwise interfere with the light source. Plants should be observed at the same time daily, and information carefully recorded.

It is suggested that the plants used in the second experiment in Part 1 be rotated in a clockwise direction each time they are turned, in order to avoid errors. Each plant should receive exactly the same amount of water and other care. Students should look for stem curvature, size and color of the leaves, and angle of the leaves in respect to the light.

Student observations—answers to questions.

- (a) Color good, leaves growing toward light source.
- (b) Leaves have good growth.
- (c) Growth is poor, color pale, leaves fail to unfold.
- (d) Leaves on the plant in box 1 are unequal in growth because of the light source; distribution of light in box 2 allows equal growth; lack of light causes loss of chlorophyll and poor growth in box 3.
- (e) The stem is growing toward the light source.
- (f) Straight, growth is good.
- (g) Tall and spindly.
- (h) Light source from one area causes unequal growth and bending; light from all areas results in healthy growth; no light inhibits growth.
- (i) All the stems were bending toward the light; leaves on the dark side were larger.
- (j) Stem curvature changed and turned toward the light; small leaves became larger.
- (k) Stem straightened up, then turned toward the light; leaves became equal.
- (l) Stem continued to bend; leaves continued to grow.
- (m) Stem straightened and began to curve toward the light; smaller leaves began to increase in size.
- (n) Stem continued to curve toward the light.
- (o) Curvature remained approximately the same.
- (p) The control.
- (q) Leaves had turned toward the light and stem curvature increased.
- (r) Leaves were larger on the dark side.
- (s) Very little change in leaves or stem curvature.

Interpretation. Light reduces the production of auxins on the light side and the cells grow more rapidly on the shady side. This increase in growth on the shady side causes the stem to bend toward the light.

B Part 2 Geotropism

Suggestions for procedure. Three experiments illustrating plant growth responses to gravity are included in Part 2. If all experiments are to be conducted, the student will require six potted coleus or geranium plants. Beans, sunflowers, or other herbaceous plants may be used. Corn or varieties of grasses will also produce interesting results in the first experiment.

For the first experiment the flowerpots should be covered with wire gauze to secure the soil in the containers. A double layer of cheesecloth may be substituted for the wire gauze. Care must be taken not to move the containers. Plants should be watered through the bottom of the flowerpots. A large syringe is useful for watering.

The second experiment in geotropism will require several monocot and dicot seeds. Corn and beans are suitable. Students should observe the growth of the roots for several days. The plates may be turned on one side or upside down after a few days and root growth again observed.

A record turntable or platform rotator with a speed of approximately 78 rpm is required for the third experiment. It is essential that the plants on the turntable be exposed to one light source only, and that light should be directly overhead. Rotation of the turntable should not be interrupted, nor should the light be turned off during the 24-hour and 48-hour periods.

Student observations—answers to questions.

- (a) This would alter the results.
- (b) Stems begin to turn upward.
- (c) Roots have turned downward.
- (d) It directs the roots downward for water and minerals.
- (e) Stems grow away from the force of gravity.
- (f) The roots always turned toward the center of gravity.
- (g) So that all plants receive the same amount of light, i.e., light does not become a variable factor.
- (h) The stems of the plants at either end of the box have turned inward. The middle plant continues to grow straight upward.
- (i) Centrifugal.

Interpretation. The stems turned toward the center of the turntable and then began to grow upward again. This was due to the fact that the stems had grown to the point in which gravity instead of centrifugal force was affecting the response of the shoot.

INVESTIGATION 23-4

Growth Stimulators in Plants

Scope of the Investigation This Investigation illustrates the effect of plant hormones on plant growth, as discussed on p. 322 of the text. Through several experiments, the student observes the effects of plant hormones on root growth, and also the effect of vitamins on growth. Part 2 gives the student the opportunity to experiment with plant growth hormones in the determination of apical dominance, which he has studied on p. 328 of the text.

Approximate time required Three experiments make up Part 1. Section 1 should re-

quire approximately 30-40 minutes for the average student to set up, followed by daily observations for 3 to 5 weeks. The final observation and drawings should be completed by the average student in a period of 50 minutes. Section 2 of Part 1 requires approximately 20 minutes for the initial preparation. The plants are left in the solution for 4-8 hours. Another preparation period of about 20 minutes is then required, followed by daily observation for 3 to 5 weeks. Section 3 of Part 1 requires 10-15 minutes preparation time followed by daily observations for 2 to 3 weeks.

Part 2 is composed of two experiments which can be easily carried on simultaneously. Preparation of the potatoes and *Bryophyllum* for the experiments can be completed by the average student within a 50-60 minute period. Daily observations follow for a period of 2 to 3 weeks.

Part 3 will require an initial preparation period of 50-60 minutes. A few minutes for observation and careful watering every day or two will be required for 3 weeks. A final period of 20 to 30 minutes will be required for the student to make his final observations and interpret his results.

B Part 1 Effect of Plant Hormones on the Growth of Roots

Suggestions for procedure. The three activities in this Part will require root-forming hormone powder, indolebutyric acid crystals, and root-forming hormone salve. A salve can be made from the powder and lanolin if the commercial salve is not available.

For each of Sections 1 and 2, six vigorous shoots of a soft-stemmed plant are required, as well as suitable containers for planting. The containers should be at least 3-4 in. in diameter, large enough to allow free root growth. Cuttings of the plants should be 4-6 in. long. It should be emphasized that with the exception of the hormone treatment, all six plants in each section should receive identical care. Watering, for example, should be done with a graduated cylinder, with each plant receiving exactly the same amount of water at the same time. Extreme care should be used when removing the cuttings to avoid any damage to the roots. Root growth of the experimental and control plants should be measured, and comparative drawings made of the root systems.

For Section 3, a single potted plant is required. It should be one with a sturdy, straight stem. The root-forming hormone salve should be applied in a band 1 cm wide around the stem, about half way up the stem. The area should be observed, and any changes in color, texture, or thickness noted. Records of any changes should be made daily for two to three weeks.

Student observations—answers to questions.

- (a) Treated plants had larger root systems.
- (b) To allow for possible death of plants.
- (c) To determine whether root-forming hormones were responsible for the increase in growth.
- (d) So as not to have more than one variable factor.
- (e) Answers will vary.
- (f) Answers will vary.
- (g) Yes.
- (h) Herbaceous stems have active meristematic tissue.

Interpretation. The addition of certain hormones to actively growing tissue will increase the rate of growth, and roots are produced more rapidly on treated plants than on controls.

B Part 2 Study of Apical Dominance

Suggestions for procedure. Six white potatoes are required for this study. Those obtained from a seed store or local gardener are preferable to those from a grocery,

since commercial potatoes are chemically treated to delay sprouting. Thus, commercial potatoes should be rinsed thoroughly to remove this chemical. The student should use a scalpel to cut the grooves in three potatoes. The groove should be made far enough down on the potatoes that a few lateral buds as well as the terminal bud are above the groove.

For the second study of apical dominance, each student will require three vigorous young leaves of *Bryophyllum*. The leaves should be prepared as shown in Fig. 23-4-b, and observed carefully for signs of new growth.

Student observations—answers to questions.

- (a) Yes.
- (b) Buds above the groove did not sprout; those below did.
- (c) Terminal buds developed sprouts; lateral buds did not.
- (d) The groove prevented the conduction of auxin, which normally inhibits lateral bud growth.
- (e) No.
- (f) Young plants grow on the tip of leaf 1 because apical dominance is present. They appear below the cut on leaf 2 because auxin cannot travel from the tip to inhibit the production of young plants. Plants also appear below the notch on leaf 3 because auxin cannot reach that area.

Interpretation. Apical dominance results in the production of terminal buds and other leaf parts in the region of auxin synthesis, and inhibition of the development of lateral buds and other leaf parts below this region. When the potato and *Bryophyllum* leaf were cut, auxin movement was interrupted, resulting in the loss of apical dominance.

B Part 3 Vitamins as Plant Growth Stimulators

Suggestions for procedure. Vitamin-B₁ solution should be prepared by the students according to instructions in their manual. Care should be taken not to damage the roots when exposing, soaking, and repotting the plants. Experimental plants should be watered with the vitamin-B₁ solution, using a volume equal to the plain water used on the control plants. All plants should receive light of the same intensity and duration. Accurate measurements are essential throughout.

Student observations—answers to questions.

- (a) Yes, should be.
- (b) Probably not.

Interpretation. Vitamin-B₁ stimulates root growth which in turn results in increased growth of stem and leaves.

INVESTIGATION 23-5

Mineral Requirements of Plants

Scope of the Investigation This Investigation serves to define further the importance of various soil minerals to the growth of plants, an idea presented to the student on pp. 321-322 of the text. Hydroponics, a method used both in research and some pilot projects in agriculture, is conducted on a limited scale in the laboratory to determine mineral requirements of certain plants. An understanding of mineral requirements should give more meaning to the student's study of the soil and problems in soil conservation when he meets them on pp. 712-714 of the text.

Approximate time required For Part 1, preparation of the stock solutions and nutrient solution could take the student up to 1½ hours. The apparatus should be set up by the average student in a period of 50-60 minutes. Three 15 minute periods per day for adding water and/or nutrient solution will be required for three to four weeks.

Part 2 will require mineral-deficient solutions which can be prepared in approximately 20 minutes from stock solutions previously prepared in Part 1. Preparation of the seeds for germination should take the student 10 to 15 minutes. After the seeds have germinated and grown to the proper size, one hour should be allowed to set up the apparatus. Every two to three days a period of 10 minutes will be required to add water and iron tartrate, and to observe the plants and record data. These observations should continue from two to four weeks.

B Part 1 Growing Plants by Hydroponics

Suggestions for procedure. Six-inch seedlings of any vigorous herbaceous plants should be grown prior to this experiment. Plants for this experiment could be from extras produced in subsequent studies. Stock solutions of the minerals should be prepared by the student according to the instructions in the student manual. Solutions can be prepared at various convenient times and stored in stoppered bottles until they are needed. The gravel used in Part 1 should be relatively fine, and washed before use. Soil should be gently washed from the roots of the seedlings before they are set in the flowerpots. The apparatus should be set up according to Fig. 23-5-a, and should be carefully checked for leaks in the connections. The nutrient solution and distilled water are allowed to flood the roots of the experimental and control plants, respectively, for 15 minutes at a time, three times a day. It is essential that both plants be in the same area, thus receiving equal amounts of light and heat. Careful observation of the leaves and measurements of the roots and stems should be made weekly.

Interpretation. A balanced mineral content is necessary for the growth and health of all parts of the plants. Only plants that had the nutrient solution had good growth of roots, stems, and leaves.

B Part 2 Effect of Mineral Deficiency on the Growth of Seedlings

Suggestions for procedure. The mineral-deficient solutions should be prepared by the student from the stock solutions previously prepared in Part 1. The jars and seedlings should be set up according to Fig. 23-5-b. The plants should be observed daily for two to four weeks. Students should note leaf production, stem strength and length, and root development, recording their data in the chart provided.

Interpretation. Lack of nitrogen and phosphorus results in stunted growth. Lack of potassium results in weak stems, poor growth, and discoloration of leaves. Iron tartrate is added because iron is essential to the production of chlorophyll.

Chapter 24

Stem Structure and Function

The study of the stem logically follows root study. The tissues are similar, especially after secondary thickening of the root. The activities of the stem are also closely related to those of the root.

Before examining the tissues of a woody

stem, the student should become familiar with its external structure. In comparing several woody twigs, certain basic similarities as well as differences can be readily seen. This is a good time to introduce tree identification on the basis of twig charac-

teristics and to teach the student what to look for in twig "personalities." In the study of branching form and stem growth, you will wish to emphasize the growing points of stems. Most people have the impression that stems grow all over rather than in certain limited embryonic regions. With this background, the student is ready to study the tissues of a woody stem and the functions of each. In teaching the forces involved in upward conduction through a stem, interesting discussions can result from various ideas as to how the stem overcomes the force of gravity in moving liquids, in some trees, more than 100 feet above the ground. Emphasize the fact that capillarity, cohesion, and evaporation pull are physical forces operating in the stem. Experiments can be planned to demonstrate the action of each force. During discussions, of budding and grafting, the vegetative propagation of roses, fruit trees, nut trees, and other budded and grafted nursery stock can be included.

When discussing the herbaceous dicot and monocot stems, emphasis should be on the general tissue arrangement in the two types of stems. The corm, tuber, rhizome, and bulb are good examples of organs modified for a special function.

Often, when trees are cut down, cross-sections may be obtained. Students may wish to make a collection of woody twigs if the woody stem is studied during the dormant season. As a vegetative propagation project, cuttings of willow and other woody stems that root readily can be rooted in water or moist sand and planted later.

P. 328: Florists also take advantage of apical dominance when they remove lateral buds and leave only one outstanding bloom.

Flowering dogwood is a tree with an easily recognizable silhouette because one lateral branch grows out beyond the terminal bud.

P. 330, left column: One heartwood man uses because of its odor and color is the red cedar.

P. 331, left column: Outer bark is used in winter to help identify deciduous trees. Cork and cinnamon both are bark.

P. 333, Fig 24-8: Have students figure out the reason for the difference between spring and summer cells.

P. 336, Fig. 24-11: Whole and sectioned stems of onion, crocus, tulip, white potato, and iris can be studied. Point out the morphological difference between white and sweet potato. Use models and prepared slides of woody and herbaceous stems to explain structure.

P. 337, left column: The time of pruning depends on the plant. Ways of pruning differ and carried to a high degree result in espaliered plants and topiary work.

P. 338, Fig 24-13: The chemistry laboratory may have a set of these tubes or one can be improvised.

Suggested Films

Stems (col, 28 min) AIBS McGraw-Hill
The Growth of Plants (b&w&col, 21 min) EBF

MAJOR CONCEPTS

1. The stems of annuals and perennials differ in structure and appearance.
2. Buds are growing regions of a stem and may be classified according to their position on the twig.
3. Young twigs have pores through which air enters and water escapes.
4. Some buds are protected by heavy scales during winter.
5. Stems grow in length by adding new tissues at their growing points located in the terminal bud.
6. Growth in diameter results from the activity of the vascular cambium.
7. As in roots, auxins control the growth of the stem and the responses to various stimuli.
8. The location of buds on the twigs determines the branching pattern of the plant.
9. The anatomy and physiology of woody and herbaceous stems are distinct.
10. Although stems function to conduct water, minerals, and dissolved food, some serve as food storage and many are specialized to serve other functions as well.
11. Transpiration pull, cohesion, successive osmosis, capillarity, and root pressure are forces that aid in raising water in stems.

ANSWERS TO QUESTIONS FOR REVIEW (Pages 339-340)

1. A herbaceous stem (buttercup) is usually soft and green and lives for only one season, growing relatively little in diameter. Woody stems contain strengthening woody tissue, are perennial, and grow to larger sizes.
2. Water loss.
3. A stem with a strong terminal bud usually grows upward as a shaft and produces an excurrent pattern of growth. When there is no terminal bud, or when the lateral buds develop freely, a spreading, deliquescent branching arrangement results.
4. The sapwood is usually light in color and has open, functioning vessels. Heartwood is darker in color, often plugged with gummy materials, and no longer functions in conduction.
5. Bark tissues include cork for protection, cork cambium, which produces new cork each season, cortex, which manufactures food in a young stem and becomes a place of storage later, and phloem, which serves as a food-conducting tissue as well as a bark-strengthening tissue.
6. The vascular cambium forms secondary xylem and rays on its inner side and secondary phloem on its outer side. This arrangement adds to the thickness of the wood and, to a lesser degree, to the bark.
7. Conduction through the rays is lateral, or across the stem.
8. In these stems, the spring wood is lighter in texture and contains many more vessels than the more dense and fiber-filled summer wood.
9. The herbaceous dicot bundle contains phloem, vascular cambium, and xylem. The monocot bundle contains phloem, xylem, and in many stems, mechanical tissue.
10. In the herbaceous dicot stem, the fibrovascular bundles lie in a zone or in a continuous cylinder. They are scattered in the monocot stem.
11. The rhizome (iris), tuber (white potato), bulb (onion), and corm (crocus).

12. Climbing stems twine around an object for support or produce tendrils that serve as a means of grasping.
13. The vascular cambiums of the stock and scion must be united.
14. Osmotic pressure is a force created by the cells as they take in water from the soil or from their neighboring cell. Capillarity is a force allowing water to rise in a tube or vessel due to the attraction of the liquid by the surface of the tube. When water is lost from the leaves, the cells nearest the atmosphere take up water from their neighboring cells. This is called transpiration pull. Cohesion is the fourth force. The attraction of one water molecule to another aids in raising water and dissolved minerals.

ANSWERS TO APPLYING PRINCIPLES AND CONCEPTS (Page 340)

1. The tissues of your body are capable of cell division. Thus growth is distributed throughout your body. Cell division in plants is restricted to areas of embryonic tissue. The branches of a tree grow in length only at terminal growing points, in embryonic tissue in lateral buds, and, in some trees, at growing points in the nodes. Growth in diameter occurs in the vascular cambium.
2. The reduced light and competition of the forest cause the trunks of trees to grow tall and straight and to branch less than the same trees would branch in an open place.
3. Girdling of the tree results in destruction of the bark tissues to the vascular cambium. With the food-conducting tissues of the phloem destroyed, the parts below the girdled area cannot receive food.
4. In open fields and prairies, plants with shortened stems receive sufficient light.
5. Loss of the leaves results in loss of transpiration pull, one of the main forces involved in the upward movement of water through a stem.

Guide to Laboratory Investigations for Chapter 24

INVESTIGATION 24-1

Woody Stems

Scope of the Investigation This Investigation gives the student an opportunity to observe in detail the structures of the woody stem that he studied on pp. 325-326 of the text. Adaptations for dormancy are well illustrated by the woody twig. From the study of a dormant twig the student should learn about leaf arrangement, branching, and age of the twig (pp. 325-326). A further understanding of the growth of stems studied on pp. 326-328 should arise from the dissection of a terminal bud in Part 2. The student who pursues Part 3 should gain further insight into the complexities of stem structure, and should become proficient in the use of twig characteristics as a means of plant identification. Apical dominance (pp. 327-329) as a determiner of branching patterns is the subject of the C-level experiment in Part 4.

Approximate time required The average student should be able to complete Parts 1 and 2 in two 50-60 minute periods.

Parts 3 and 4 are long-range projects for the individual student and may require several weeks to a few months for a thorough study.

A Part 1 External Structure of a Woody Twig

Suggestions for procedure. Woody twigs for this study should be collected in winter or early spring while the buds are still dormant. Terminal buds as well as lateral buds should be present, and the twig should exhibit several seasons' growth.

Student observation—answers to questions.

- (a) Answers will vary.
- (b) No.
- (c) Weather conditions and position on a tree determine the growth in length of the internodes.
- (d) Answers will vary according to twig used.
- (e) No.
- (f) All leaf scars of a twig will have the same number of bundle scars, and their arrangement on the twig will be the same.
- (g) Answers will vary according to twig used.
- (h) Respiration.

A Part 2 Dissection of a Terminal Bud

Suggestions for procedure. A twig with a large terminal bud is required for this study. Students should work carefully with scalpel and forceps to remove the bud scales, one pair at a time. They should be cautioned against cutting too deeply and damaging the bud. When the scales are removed, they should be placed on a piece of paper in the order in which they were removed, and their arrangement noted. Sectioning of the meristematic region should be done with extreme care, using the dissecting microscope. The scalpel or razor blade used for this sectioning should be extremely sharp and quite thin.

Student observations—answers to questions.

- (a) The innermost scales are the largest.
- (b) They reduce the loss of water and protect the meristematic region from injury.

- (c) Answers will vary according to twig used.
- (d) Yes, if leaf scars are alternate, the bud scales will also be alternate. They are arranged in the same manner as the leaf scar arrangement.

B Part 3 Comparison of Twig Structures

Suggestions for procedure. The student should be equipped with one or more identification keys to the trees. For trees of the central hardwood area, Charles Otis' *Michigan Trees*, published by the University of Michigan Press, is of value. The student should completely familiarize himself with the use of the keys before he begins collecting specimens. Data should be recorded in the table, and each specimen identified as to genus and species.

Interpretation. Through knowledge of winter twig characteristics the forester can identify the trees at any season of the year.

C Part 4 Apical Dominance in a Terminal Bud

Suggestions for procedure. For this study, two very young spruce, fir, or pine trees are required. They should be the same size and age. Pruning shears are used to remove the uppermost stem tip of the experimental tree. The growth of the first whorl of branches below the tips of both trees should be carefully observed.

Analysis and conclusions. The student should account for his results in terms of apical dominance. When the leader was removed, auxin could not be synthesized and translocated to the lateral branches where it would inhibit growth. Lateral branches on the control will continue to grow in a whorl because auxin produced in the tip of the leader inhibits their growth.

INVESTIGATION 24-2

Stem Tissues

Scope of the Investigation In this Investigation the student observes the microscopic structure of the tissues that he located in the stems and diagrams of Investigation 24-2, and that he studied on pp. 329-334 of the text. Through this study he should gain understanding of how the cellular structure and location of the various tissues are adaptations for successful functioning of the stem as a plant organ (p. 333). If the student pursues the C-level Part 3, he will demonstrate the use of stems as a means of plant propagation, as discussed on pp. 336-337 of the text.

Approximate time required Parts 1 and 2 should each require a period of 50-60 minutes for the average student to complete.

Part 3 will require an initial preparation period of approximately 35 minutes, and a few minutes for daily observation and care for a period of three or four weeks.

A Part 1 Tissues of a Woody Dicot Stem

Suggestions for procedure. Prepared slides of a cross section of a woody stem are required for Part 1. Basswood (*Tilia*) is good. The student should study the entire slide carefully under low power, moving in an orderly manner from the center outward. Each tissue should be examined as to location and cell types. High power may be used to study the structure of individual cells. The basic drawing should be made from the low-power view, and high power used when cellular detail is added to the drawing.

Student observations—answers to questions.

- (a) Thin walled.
- (b) Two or three.
- (c) No.
- (d) Lateral conduction of food and water and food storage.
- (e) In the cortex.
- (f) Yes, they may differ in kind, arrangement, size, and thickness of the cell walls.
- (g) Part of the annual ring is formed in the spring, when water is plentiful, and the other portion is formed during the summer when less water is available.
- (h) Variable.
- (i) Conduction of water and minerals.
- (j) Giving strength to wood.
- (k) One, but this is difficult to see.
- (l) Phloem and xylem.
- (m) Xylem.
- (n) The wood area of a stem is greater than its bark thickness.
- (o) In the center of the stem.
- (p) Conduction.
- (q) Support and strength.
- (r) Cork replaces the epidermis, keeping out the light.
- (s) Yes.
- (t) No.
- (u) They have thick walls and appear empty.
- (v) The cork layer splits as the stem grows in diameter. Thus, new cork cells must be produced.
- (w) Producing cork cells.
- (x) It protects the stem from loss of water and mechanical injury.

A Part 2 Tissues of Herbaceous Dicot and Monocot Stems

Suggestions for procedure. Prepared slides of stems of a herbaceous dicot, such as buttercup (*Ranunculus*), and a monocot, such as corn (*Zea*) are required. The same procedure should be followed as in Part 1, using low power for a general study before utilizing high power for cellular detail.

Student observations—answers to questions.

- (a) One.
- (b) Some should be found.
- (c) Answer depends on the kind of stem.
- (d) The xylem.
- (e) The phloem.
- (f) It lives for only one growing season in cold climates.
- (g) The cells are thick-walled.
- (h) Pith.
- (i) They are scattered in the pith.
- (j) No.
- (k) Monocots can grow in diameter only until their cells have reached a maximum size.

C Part 3 Plant Propagation by Stem Cuttings

Suggestions for procedure. Potted geraniums or other herbaceous plants are required for this study. Cuttings should be made according to directions in the student manual, and planted in moist, sandy potting soil. The plants should be covered carefully with a piece of plastic to retard transpiration. The plants should be placed in an area where

they receive sufficient light, and the temperature should be from 23 to 27°C. Students should be cautioned against over- or under-watering. At the end of three weeks all specimens should be observed for evidence of new stem, branch, or root growth. They then may be replanted for future observation.

Analysis and conclusions. Evaporation is a problem to plants that lack roots to absorb large quantities of water. The students should find that the presence of leaves retarded growth in their cuttings. The stem area has little effect on regeneration. Roots form at the base of the stem and lateral buds develop into shoots.

INVESTIGATION 24-3

Conduction in Stems

Scope of the Investigation This Investigation illustrates the path water takes in rising through a stem, which the student has studied on p. 332 of the text. The student also experimentally determines the rate of water movement through stems. This movement is due to the forces of transpiration pull, capillarity, and cohesion, as discussed on pp. 337-338 of the text.

Approximate time required The average student should be able to set up all cuttings and branches for Part 1 in a period of 50-60 minutes. If the fresh stems are prepared first in the period, they should be ready for observation by the end of the period. Others should be observed several hours later, or the next day, at which approximately 20 minutes should be required. The branches bearing leaves should be observed 24 hours later.

The initial preparation of the plants in Part 2 and the observation of the first 3 or 4 plants can be completed in a 60-minute period. Another observation at the end of the day should require 10-15 minutes, as should a final observation 24 hours later.

A Part 1 The Path of Rising Water in a Woody Stem

Suggestions for procedure. A fresh stem cutting at least 2 feet long is required, as well as two 2 to 3-foot branches bearing leaves. Maple, elm, or similar woody species may be used. Other materials include melted paraffin, a brush, and powdered eosin (or red ink). The fresh stem should be cut under water six inches from the base, and then should not be removed from the water. The eosin or ink should be added, and the stem secured and left 30 minutes to several hours. After a longitudinal section is made, the tissues should be observed with a hand lens, noting especially the bark, xylem, and wood. The two branches bearing leaves should be prepared as instructed in the student manual, Fig. 24-3-a. Care should be taken that only the tissues specified are covered with the paraffin. Students should be cautioned against the hazards in melting and handling hot paraffin. The stems thus prepared should stand in water for 24 hours, after which the color and condition of the leaves should be noted.

Student observations—answers to questions.

- (a) No.
- (b) Yes.
- (c) No.
- (d) Leaves are very healthy, turgid, and green.
- (e) Water was conducted to leaf tissues and the cells became turgid. Photosynthesis could also occur.
- (f) The leaves were wilted, limp, and light green in color.
- (g) Water was not available to the tissues because the xylem cells were blocked.

A Part 2 The Rate of Water Rise Through a Stem

Suggestions for procedure. Six 15-20 cm cuttings of coleus, periwinkle, or other herbaceous plants are required. All should be of the same species, size, and vigor. The cuttings should be placed in water colored bright red with eosin or red ink, and one cutting sectioned and examined every 15 minutes throughout the laboratory period. Another may be observed at the end of the day, and another 24 hours later. All time intervals and distances should be carefully recorded.

Student observations—answers to questions.

- (a) Yes, probably.
- (b) Answers will vary.
- (c) Transpiration pull is an important factor in the rise of the water in stems.

Chapter 25

Leaf Structure and Function

This chapter, on the leaf and its activities is, in a sense, a climax study of the vegetative organs of the seed plant. The processes of the root and stem relate directly to the vital chemical activities of the leaf.

In the study of the gross external structure of the leaf, you will probably wish to emphasize leaf characteristics that are used in identifying plants. It is interesting to point out similarities in the leaves of plants in one genus as, for example, similarities in oak, maple, or ash leaves. The study of leaf tissues is a splendid lesson in adaptation. Each part of the leaf is ideally suited to the functions the leaf performs.

Major emphasis should be placed on photosynthesis. The complimentary relationship of photosynthesis and respiration is an important biological lesson because it illustrates the cycle of matter and the dependence of nongreen plants and animals on the ability of the green plants to utilize inorganic compounds in the formation of organic ones. An interesting discussion can center around the duplication of the process in the laboratory and the fact that chlorophyll has been synthesized. Point out that much of our civilization has depended on wood, coal, oil, and other fuels of photosynthetic origin. Other functions of the leaf are ideal subjects for class discussions and for simple experiments and projects in plant physiology.

P. 343, Fig. 25-2: Use the diagram to

discuss the function of each structure. Review the importance of the cuticle to plants in general and the evergreens in particular.

P. 344-345: Questions for thought—Why do leaves that float on the surface of water have stomates on the upper surface? Why is there such a difference in the leaf structure of plants growing in shade and sunlight (Fig 25-5)?

P. 345, right column: Insectivorous plants may be obtained from a biological supply house, mail order house, or local outlet. Here the practice of conservation should be considered.

P. 348, left column: In a comparison of photosynthesis and respiration, review chemical equations on pp. 84, 86, 99, and 100. Chlorophyll has been synthesized in the laboratory.

Discuss leaves in relation to man (economic botany). He uses them for food (lettuce, cabbage, spinach, chives, and basil) and shelter (palm). Two plants that have many uses besides food, shelter, and clothing are the coconut and bamboo. The story of their uses and place in history makes for interesting reading.

Suggested Films

How Green Plants Make and Use Food (b&w&col, 11 min) Cor
Leaves (col, 28 min) AIBS McGraw-Hill
Photosynthesis (col, 21 min) EBF
The Role of Green Plants (col, 28 min) AIBS McGraw-Hill

MAJOR CONCEPTS

1. Although the major function of a leaf is photosynthesis, many have specialized functions as well.
2. Leaves vary greatly in size, shape, and arrangement on the stem.
3. Stomates control the passage of gases and water into and out of the leaf.
4. Although stomates may occur on both surfaces of a leaf, they are more numerous in the lower epidermis.
5. Individual leaves can adjust the position of their blades by a bending of the petiole as a response to light.
6. Light influences leaf growth in the makeup of internal tissues.
7. Moisture also affects the size and growth of leaves.
8. Leaves contain pigments other than chlorophyll.
9. Leaves obtain energy from oxidative processes and, therefore, respire as well as photosynthesize.

ANSWERS TO QUESTIONS FOR REVIEW (Pages 350-351)

1. The leaf blade, being thin and broad, allows the cells to receive the maximum amount of light. It also permits the greatest intake and discharge of gases through the stomata of the lower epidermis.
2. Veins form a supporting network for the blade and are the channels through which water and dissolved minerals and foods are conducted.
3. Dicot leaves have branching, netted veins while the veins of the monocot leaves are in a parallel arrangement.
4. Upper epidermis, palisade layer, spongy layer, lower epidermis. A cuticle is formed on the surface of the upper epidermis in many leaves.
5. The spaces of the spongy layer allow diffusion of gases between the cells and the air entering the stomata and receive excess water as vapor.
6. The stomates lie in the lower epidermis of most leaves, although they may be in both epidermal tissues in a vertical leaf and in the upper

epidermis in a floating leaf. A stoma consists of an elliptical opening between two oval or rounded guard cells. The stomates are partially controlled pores through which gases enter and are discharged from the leaf tissues. The size of the pore is regulated by change in shape of the guard cells, which is in turn controlled by water content changes.

7. Generally speaking, plants which grow in humid regions, as in the tropics, have large leaves. Plants of the dry plains or deserts, where the atmospheric humidity is very low and where water loss from leaves would be great, have small leaves or none at all (as in the cactus).
8. Various pigments appear in leaves in the fall when the chlorophyll, which has been masking them through the summer, breaks down and disappears on bright, cold days. Anthocyanin, a red pigment, is produced in the cell sap during cool weather.
9. As photosynthesis occurs in the guard cells, more starch is converted to sugar. Since the concentration of water then becomes less than in the surrounding cells, water diffuses into the guard cells by osmosis. The opening of the stomates is controlled by the water content of the guard cells. When the guard cells are full of water, the stoma is open. When the guard cells lose water, they change shape and the stomates close, thus reducing water loss.
10. In photosynthesis, water and carbon dioxide are chemical raw materials, energy is absorbed, glucose is the product, and oxygen is the waste product. In respiration (oxidation), the process is reversed. Glucose and oxygen are combined chemically, energy is released, and water and carbon dioxide are released as waste products.
11. The water content of the plant regulates the turgor and, therefore, the shape of the guard cells of the leaf stomata. This, in turn, regulates the

size of the stomate pores and the rate of transpiration. The water content of the atmosphere determines the rate of movement of water vapor from the leaf surface.

ANSWERS TO APPLYING PRINCIPLES AND CONCEPTS (Page 351)

1. The thin walls of leaf cells permit rapid movement of water, minerals, dissolved foods, and gases into and out of them. This is necessary in the many processes leaf cells carry on.
2. As carbon dioxide is used up in photosynthesis, the series of events described in the answer to question 9 occurs, opening the stomate and admitting more carbon dioxide.
3. If a plant used all of the food it

produced in maintaining its own life, there would be none left to support dependent plants and animals.

4. There is little scientific reason for removing plants from a sick room at night. It is true that when photosynthesis stops, the plant absorbs oxygen from the atmosphere to support its respiration. However, the amount of oxygen used would not affect the patient. The best reason for removing plants is psychological. It gives the patient a change of scenery and adds to the pleasure of seeing them again the following day.
5. Pruning for leaf removal after planting is practiced to reduce transpiration until new roots can increase water absorption to the normal rate. This is a very important precaution in moving trees and shrubs during the growing season.

Guide to Laboratory Investigations for Chapter 25

INVESTIGATION 25-1

Tissues of the Leaf

Scope of the Investigation This Investigation presents to the student an examination of the leaf structures he studied on pp. 343-344 of the text, and aims at a further understanding of their role in photosynthesis as presented on pp. 344-347.

Approximate time required The average student should be able to complete Part 1 in a period of 50-60 minutes, and Part 2 in a similar period of time.

A Part 1 Tissues of the Leaf

Suggestions for procedure. Prepared slides of cross sections of a leaf are required for Part 1. Lilac (*Syringa*) is especially good. The student should scan the entire slide under low power before selecting a section to study in detail under high power.

Student observations—answers to questions.

- (a) One or two.
- (b) Usually.
- (c) It prevents loss of water.
- (d) They are arranged at right angles to the upper epidermis.
- (e) Photosynthesis.
- (f) This permits greatest transmission of light throughout the cell.
- (g) The palisade layer.
- (h) Yes.
- (i) Probably not.
- (j) Spongy cells do not receive as much light as the palisade cells.
- (k) They allow gases to diffuse through the internal portion of the leaf.
- (l) Conduction of water and minerals.

- (m) Conduction of food.
- (n) Xylem.
- (o) One.
- (p) Exchange of gases (carbon dioxide for photosynthesis and oxygen for respiration); regulation of loss of water vapor to the outside air.
- (q) They open into the air spaces.

A Part 2 Study of the Lower Epidermis

Suggestions for procedure. Living leaves of geranium or *Tradescantia* (spiderwort) are suggested for Part 2. A wet mount of the epidermis should be made according to the instructions in the student manual, noting especially the warning against letting the tissue dry out. The wet mount should be observed, noting carefully the stomates, and the drawing completed. A second wet mount should be made according to instructions, observed, the 10% salt solution added, and the tissue observed again.

Student observations—answers to questions.

- (a) No.
- (b) No, the inner walls are thicker than the outer ones.
- (c) Yes.
- (d) Water vapor moves out, oxygen moves out, and carbon dioxide moves into the leaf.
- (e) Carbon dioxide.
- (f) They regulate water loss. When guard cells are turgid, the stomates are open. When the guard cells lose their turgor, the stomates close.
- (g) If the plant has been exposed to bright light, the stomates will be open.
- (h) The guard cells changed shape, resulting in the closing of the stomates.
- (i) The salt concentration outside the cell caused the guard cells to lose water, and the stomates were closed.
- (j) Synthesis of carbohydrates. CO_2 is used up and the acid content of the guard cell decreases. More starch is converted to sugar; water diffuses into the guard cells and the stomates close.

INVESTIGATION 25-2

Transpiration in Plants

Scope of the Investigation This Investigation illustrates to the student the process of transpiration which he has studied on pp. 349-350 of the text, and gives him an opportunity to determine the amount of water lost during transpiration. He also considers in this Investigation the factors that influence transpiration (p. 350).

Approximate time required In Part 1, significant results should be obtained at the end of a 50-60 minute period. If desired, the apparatus can be left intact, and observed over a period of several hours or days.

Part 2 will require an initial preparation period of 15-20 minutes. (If the same plant is used as in Part 1, only time to weigh it will be required on the first day.) Approximately 5 minutes will be required for daily weighing and observation each day for 5 days.

A Part 1 Transpiration in Plants

Suggestions for procedure. A potted geranium plant is required for Part 1. Be sure to select a healthy, vigorously growing plant. Also required is cobalt chloride paper and a piece of aluminum foil or thin rubber sheeting. The plant should be prepared as di-

rected in the student manual, and placed under a bell jar. Note that both jars are to be placed in a sunny area. Cobalt chloride paper, which is put in each jar, is an indicator of moisture. It is blue when dry, but turns pink in the presence of moisture.

Student observations—answers to questions.

- (a) Blue.
- (b) Pink.
- (c) Blue.
- (d) Moisture released during transpiration from the geranium leaves caused the cobalt chloride paper to change from blue to pink.
- (e) Water droplets have formed on the walls.
- (f) The walls are clear.
- (g) The living geranium plant in one jar was losing water through transpiration.
- (h) To prevent loss of water from the soil as a variable factor.
- (i) To demonstrate that the water on the walls of the jar came from the plant.
- (j) Transpiration is the loss of water from an active leaf.

B Part 2 Determination of the Amount of Water Lost During Transpiration

Suggestions for procedure. A potted geranium is also needed for Part 2. The same plant can easily be used that was used in Part 1, for the manner of preparation is exactly the same. The plant should be weighed carefully each day for five days, and the weight losses calculated and recorded in the table provided.

Student observations—answers to questions.

- (a) Very small.
- (b) Water loss was not great enough. The leaves were supplied with water from the soil.
- (c) Air currents, humidity, temperature, light, soil factors.

Interpretation. The atmosphere becomes cooler and absorption makes up the water deficiency. The stomates remain closed for longer periods of time at night, thus reducing the evaporation rate.

Chapter 26

Reproduction in Flowering Plants

The study of flowers relates to several areas of biology. It continues the study of the seed plant and the functions of its specialized organs. In our study of heredity, we have already referred to pollination and to methods of controlling this process in plant breeding. In addition, flower study can serve as an introduction to flower gardening and beautification projects which are often included in biology courses.

In teaching the parts of a flower, it is important that essential and accessory parts be distinguished. Students often think of flowers only in terms of bright petals and fragrance, without realizing that many plants such as maple, ash, and walnut trees

are just as much flowering plants as are the rose, geranium, or lily. The modification of flowers and the various agents of pollination are good lessons in biological interdependence because they show the dependence of living things on physical factors, such as wind and water. The story of the growth of the pollen tube, formation of the egg and endosperm nucleus, and double fertilization is an excellent example of sexual reproduction. Since materials for flower study in the laboratory are abundant, much of the material in this chapter can be taught by means of first-hand observation.

The development of fruits and seeds cli-

maxes reproductive activity and closes the study of seed plants. We have selected familiar fruits, representing both fleshy and dry types, as examples to show the development of the pistil and associated parts of the flower into the fruit. The table on p. 360 classifies many other familiar fruits as fleshy, dry dehiscent, or dry indehiscent. You may wish to add other familiar local fruits the students know. Class discussions should include modification of fruits and seeds for various kinds of dispersal. A class collection of fruits and seeds will add much to the interest in classification and in methods of dispersal. The fruits may be grouped on a cork board or pieces of cardboard according to classification. The agent of dispersal should be indicated on the label for each specimen.

Kodachrome slides or colored pictures for opaque projection of wildflowers and garden flowers are excellent supplementary materials for this chapter. A flower collection project is also good if the local flora are available and if students are cautioned not to destroy plants in removing the flowers.

If possible, include some germination experiments in this study. Both bean and corn are good. In addition to studying various stages in germination and growth of the young plants, various conditions affecting germination, such as heat and cold, light and darkness, water and dryness can be tested.

P. 352, right column: Bring in, if possible, flowers of trees like oak, elm, maple, or birch. Students do not realize that pussy willows are flowers. If these are allowed to mature, the male and female flowers can be seen. Grasses under a hand lens reveal beautiful colors and shapes.

P. 356, right column: Examples of flower adaptations for pollinating can be secured from films, pictures, or specimens. The mountain laurel has an unusual mechanical adaptation. When stepped on, the stamens spring inward toward the center of the flower and brush the insect with pollen. The common violet has both cross and self-pollination and cleistogamous flowers, which rest at the base of the plant and never open.

P. 357, left column: Sweet odors and

carriion-like odors both attract insects. The skunk cabbage is an example of the latter.

P. 358, Fig. 26-5: This diagram will mean more if a demonstration is set up by the student or the teacher. Pollen grains will germinate if put in a dilute sugar solution about two hours or more prior to the time needed for microscope study.

P. 361, Fig. 26-6: Use local specimens. If possible, have students use a hand lens to see structures like hooks which are not visible otherwise. A collection of many seeds can be kept on hand for study in the laboratory.

P. 365, Fig. 26-10: These fruits or similar ones can be brought to the laboratory for study. An avocado can be grown by placing the seed in a glass with water touching the bottom of the seed. Toothpicks stuck in the seed will prevent it from falling into the water. The table on p. 360 will suggest other fruits for study.

P. 366, left column: Some seeds do not germinate in any number unless they first undergo a cold period corresponding to the natural seasonal changes. Botanists get around this by keeping the seeds for a time in the refrigerator.

P. 368, right column: Soy beans and Mung beans are easily sprouted and can be eaten raw. They are used in Chinese cooking and have high nutritive value.

Suggested Films

Flowers: Structure and Function (b&w&col, 11 min) Cor

Plant Reproduction (col, 28 min) AIBS McGraw-Hill

Reproduction in Plants (b&w&col, 13½ min) Cor

Seeds and Germination (col, 28 min) AIBS McGraw-Hill

MAJOR CONCEPTS

1. The flower is a specialized structure of the angiosperms which is adapted for reproduction of the species.
2. A flower is a modified branch in which the leaves are very much altered to form the various parts.
3. Although some flowers may lack either stamens or pistils, many have both.
4. The male gametophyte is formed in the anther and is called a pollen grain.

5. The female gametophyte is formed in the ovary.
 6. The gametophyte generations are, therefore, microscopic and parasitic upon the sporophyte.
 7. A seed is an immature sporophyte protected by one or more coats.
 8. Pollination is the transfer of a pollen grain from an anther to the stigma of either the same flower or another flower.
 9. Variations in flower structure may adapt them for very specialized mechanisms of pollen transfer.
 10. Flowers develop a variety of fruits.
 11. Fruits and seeds may have very specialized structures for dispersal.
 12. Seeds contain food for nourishing the embryo during germination.
 13. Seeds of monocots and dicots differ.
 14. Moisture, correct temperature, and oxygen are requirements for germination of most seeds.
6. The formation of the pollen tube begins when the pollen grain lodges on the stigma. This tube penetrates the stigma, lengthens and grows through the soft tissue of the style until it reaches the micropyle of the ovule. The tube nucleus remains near the top of the pollen tube during growth, and the generative nucleus moves into the tube. The generative nucleus divides to form the two male gametes, or sperm. The pollen tube digests its way through the thin wall of the embryo sac. The tip of the tube nucleus ruptures and the two sperm are discharged into the embryo sac.
 7. One sperm unites with the egg in fertilization, producing the zygote. The second sperm unites with the polar nuclei in the embryo sac or in some types of flowers, with a primary endosperm nucleus formed by the fusion of the polar nuclei just prior to fertilization.
 8. The zygote forms a mass of tissue which becomes the embryo plant. The endosperm nucleus forms a mass of tissue which becomes the endosperm of the seed.
 9. After fertilization, the ovary of the pistil and, in some flowers, other parts such as the calyx or receptacle, develop into the fruit.
 10. The fruit protects the seeds it encloses and provides an attractive device as means of seed dispersal.
 11. These fruits illustrate mechanical dispersal, accomplished by a sudden twisting of the walls of the pod as it dries out during the ripening process.
 12. Fleshy fruits like the cherry, raspberry, and apple may be carried by birds and other animals. The seeds may be dropped a considerable distance from the parent plant. Burs and sticktights cling to the fur of animals and travel long distances.
 13. Dandelion fruits and milkweed seeds are dispersed by the wind. They are equipped with fine, fluffy, parachute-like hairs which are easily carried away by air currents.

ANSWERS TO QUESTIONS FOR REVIEW (Page 370)

1. Sepals protect the flower parts in the bud stage and help support the petals after opening. Petals are attractive devices associated, for the most part, with insect pollination.
2. Microspore mother cells contain the diploid ($2n$) number of chromosomes, while microspores contain the haploid (n) number.
3. The division of a megaspore mother cell is followed by a division of the daughter cells, resulting in a row of four megaspores. These megaspores contain the haploid (n) number of chromosomes. Only one of the four megaspore survives; the other three disintegrate. The remaining megaspore enlarges rapidly and forms an oval embryo sac in which further development prepares the ovule for fertilization.
4. The egg is the center nucleus nearest the micropyle; the two synergids lie on either side; two polar nuclei lie in the center of the embryo sac; and three antipodal nuclei are in the end farthest from the micropyle.
5. Insects, wind, and water.

14. Moisture, proper temperature (60° to 80°F for many seeds), and oxygen.
15. The leaves of the corn seedling penetrate the soil by being rolled tightly and enclosed in a protective sheath.

ANSWERS TO APPLYING PRINCIPLES AND CONCEPTS (Pages 370-371)

1. Huge quantities of pollen are necessary to guarantee fertilization of a relatively small number of ovules. Especially in wind pollination, much of the pollen never reaches the pistil.
2. In the early spring, the leaves of trees have not developed. These would interfere with wind pollination of the flowers.
3. Insect-attracting devices include brightly colored petals, nectar guides, nectar, and perfume glands.
4. The sperm nucleus has to pass through the pollen tube in order to unite with the egg nucleus of the ovule.
5. In the mosses, the gametophyte generation is the dominant one. Gametes are shed and when a drop of water covers the plant, gametes unite to form the zygote. The development of the zygote forms the sporophyte generation, which is parasitic upon the gametophyte. In the angiosperms, however, the sporophyte generation is dominant. The male gametophyte is small and may be carried by the wind, water, or by animals to a stigma of a flower where it grows, produces sperm, and fertilizes the ovum which is contained within the flower. Angiosperms, then, are less dependent upon water for the continuation of the life cycle and the mechanisms of reproduction allow recombination from widespread areas. This allows for more variation to occur.
6. The seedling requires considerable moisture until its root system has become established. This moisture must be present, also, to soften the seed coats and allow germination to begin. This is a natural safeguard against germination under unfavorable moisture conditions.
7. Seeds enclosed in heavy clay or planted too deep do not receive sufficient oxygen for germination.
8. Starch is insoluble and cannot enter cells for use. The change of starch to sugar by the action of amylase allows food to enter the tissues of the embryo and supplies energy for activities involved in germination.

Guide to Laboratory Investigations for Chapter 26

INVESTIGATION 26-1

The Flower—Specialized Reproductive Structure

Scope of the Investigation This Investigation acquaints the student with the various types of flowers as discussed on p. 354 of the text, and gives him the opportunity to observe the flower structures which he studied on pp. 352-354.

Approximate time required The average student should be able to complete this Investigation in a period of 50-60 minutes.

A Part 1 Structure of a Flower

Suggestions for procedure. The student should study the diagrams in Fig. 26-1-a carefully, and first determine whether the flower is complete or incomplete, and perfect or imperfect. He should then determine whether the imperfect flowers are staminate or pistillate. The student should then focus his attention on the large flower specimen and answer the questions concerning the parts. In Section 2 the student should carefully dissect the parts of the flower, making the required sections and drawings. If the stu-

dent's scalpel is not very sharp, he should use a razor blade in sectioning the anther and pistil to avoid damaging these structures.

Student observations—answers to questions.

- (a) 1. Willow—incomplete, imperfect (both staminate and pistillate flowers are shown)
- 2. Lily—complete, perfect
- 3. Sunflower—ray flowers: incomplete, imperfect; disk flowers: incomplete, perfect
- 4. Corn—incomplete, imperfect (both staminate and pistillate flowers are shown)
- 5. Sweet pea—perfect, complete
- (b) Answers will vary.
- (c) Answers will vary.
- (d) Answers will vary.
- (e) Answers will vary.
- (f) Should be able to see them.
- (g) They give color to the petals and/or sepals.
- (h) They should be in proportion; if a monocot, three or multiples of three; if a dicot, multiples of four or five.
- (i) Answers will vary.

INVESTIGATION 26-2

Structure and Germination of Pollen Grains

Scope of the Investigation This Investigation enables the student to observe various types of pollen grains and to study their structure, as discussed on pp. 354-355 of the text. The student also is enabled to observe the germination of pollen grains and the growth of pollen tubes he has studied on pp. 357-358 of the text.

Approximate time required The time required by the average student to complete Part 1 will depend on the number of different kinds of pollen to be studied. Approximately 15 minutes should be required to stain, observe, identify, and draw each specimen.

Part 2 should be completed by the student in a period of 50-60 minutes, depending on the type of pollen used.

Parts 3 and 4 are long-range projects for the individual student interested in pursuing his study of pollen tube formation and the morphology of pollen grains.

A Part 1 Examination of a Variety of Flower Pollens

Suggestions for procedure. A variety of flower pollens are required for all Parts of this Investigation. It is suggested that the students collect these pollens in small envelopes for some time prior to the study. Suggestions as to types of flowers are found in the student manual. Wet mounts should be made of each type of pollen, using methylene blue or crystal violet as a simple stain. Only very small amounts of the stain should be used, to avoid making the slide too dark. The slide should be warmed *gently* over a flame if the pollen grains do not stain readily. Heating too long or too strongly may cause the stain to spatter or the slide to break.

B Part 2 Germinating Pollen Grains

Suggestions for procedure. Students should once again provide themselves with a collection of flower pollens. They should prepare a 10% sucrose solution as instructed in the student manual. Hanging-drop preparations of the pollen grains and sugar solu-

tion should be made and sealed with petroleum jelly to prevent evaporation. The slides should be observed under low power. If an assortment of pollen grains have been used, some should begin to produce pollen tubes within 20 minutes. A tube should be selected, observed, and drawn in several stages of development.

Interpretation. The sugar solution provides a condition similar to the concentration of sugar on the stigma of the pistil, thus simulating the natural conditions which initiate pollen tube growth.

B Part 3 Variation in the Germination of Pollen Grains

Suggestions for procedure. The student should prepare 5%, 10%, 15%, 20%, 25% and 30% sucrose solutions. Hanging drops of the same kind of pollen should be prepared in each of the solutions, and the growth of the pollen tubes compared. The student should also use several different pollens in a 10% solution and compare their growth. One species of pollen should be observed in a variety of 10% solutions, including maltose, lactose, glucose, or honey.

Interpretation. Pollen grains do not form pollen tubes on the stigmas of flowers that do not provide the proper environment for germination. Pollens from plants with sticky stigmas require longer periods for germination in a low sugar concentration.

C Part 4 Generic Similarities in the Morphology of Pollen Grains

Suggestions for procedure. The student must collect pollens from several different species of the same genus for this study. Wet mounts prepared as in Part 1 should reveal the structure of the grains. Shape, size, and characteristics of the exine of each should be noted, and drawings made.

Analysis and conclusions. Important characteristics of pollen grains are the size, shape, and nature of the exine. Size differences should be seen among the different species. However, similarities in general form and the characteristics of the exine layer should be obvious in members of the same genus. For example, many of the conifers bear bladderlike wings on the pollen grains, while the composites have spines, and the birches have three small protuberances.

INVESTIGATION 26-3

The Fruit—A Matured Ovary

Scope of the Investigation This Investigation guides the student in a study of the structure of typical fleshy and dry fruits, discussed on pp. 359-360, 364-365 of the text, and aids the student in relating various fruit structures to the flower structures from which they originated.

Approximate time required The average student should be able to complete this Investigation in a period of 50-60 minutes, each Part requiring approximately 30 minutes.

A Part 1 Fleshy Fruits

Suggestions for procedure. This Part will require examples for a pome, such as an apple or pear, and a drupe, such as a peach, plum, or cherry. The apples should be carefully selected as to be as complete as possible. Often those that have been washed and polished to make them commercially attractive have had the sepals and stamens removed in the process. Thus, apples picked directly from the tree or obtained from a

local orchard are often better for study than those purchased from a grocery store. The students should observe the fruits carefully, making the required sections and drawings.

Student observations—answers to questions.

- | | |
|---------------------------|------------------|
| (a) Pear or quince. | (e) Seed. |
| (b) Calyx and receptacle. | (f) Fleshy part. |
| (c) Fleshy part. | (g) Ovary wall. |
| (d) Seed. | |

A Part 2 Dry Fruits

Suggestion for procedure. For Part 2 an assortment of dry fruits is required, including a legume, such as a bean or pea, and an achene with pappus, such as dandelion or goatsbeard. The legume is easier to study if the seeds are well developed and the pod is beginning to dry. It should be noted that the pod should be opened along the lower side, as not to disturb the placental connections of the seeds.

Student observations—answers to questions.

- (a) It splits open to scatter the seeds.
- (b) It does not split open to scatter the seeds.

INVESTIGATION 26-4

The Seed—A Matured Ovule

Scope of the Investigation This Investigation enables the student to observe in detail the structure of the seeds he studied on pp. 362-366 of the text, with emphasis on the structure of the embryos and the areas of food storage.

Approximate time required The seeds studied in Part 1 must be soaked overnight, but the actual observations should be completed by the average student in a period of 50-60 minutes.

A Part 1 Structure of Seeds

Suggestions for procedure. The lima beans and corn should be soaked overnight prior to their observation. Students should observe all external structures and make their external drawings, and then should carefully remove the tests, using caution not to damage the embryo. When the iodine is added, it should be used in limited quantities to avoid obscuring small details of structure.

Student observations—answers to questions.

- | | |
|---|-----------------|
| (a) It allows the pollen tube to enter. | (e) Blue black. |
| (b) Fleshy. | (f) Starch. |
| (c) Food storage. | (g) Starch. |
| (d) The cotyledons. | |

INVESTIGATION 26-5

Seed Germination

Scope of the Investigation This Investigation enables the student to observe the germination of seeds, a process which he studied on pp. 366-369 of the text. He can

note the differences in germination of monocot and dicot seeds. He also can demonstrate the effect of various environmental conditions on germination and thus determine the requirements for proper germination.

Approximate time required Part 1 will require an initial preparation time of 10-15 minutes, and 10 minutes for daily observation and care for two weeks.

Part 2 will require approximately 30 minutes to set up, and 10 minutes daily for one week.

Part 3 will require 20-30 minutes to set up, and daily care and observation for one week.

If all three Parts of the Investigation are to be carried out, they could very easily be run simultaneously. All could be set up within an hour, and the weeks of observation could run concurrently.

A Part 1 Steps in Germination of a Dicot and Monocot Seed

Suggestions for procedure. In addition to normal laboratory equipment, seeds of bean and corn and sawdust are required in this Part. Students should prepare germination glasses according to directions in the student manual. Beakers may be substituted for the tumblers. Note that the sawdust should be merely *damp*. Students have a tendency to over-water their seeds. In observing the seeds, students should avoid moving the paper liner or otherwise disturbing the germinating seeds.

Student observations—answers to questions.

(a)	Corn germination	Bean germination
	Hypocotyl does not grow above ground	Hypocotyl grows above ground
	Cotyledon does not grow above ground	Cotyledon grows above ground
	Primary root is temporary	Primary root is permanent
	First leaves enclosed in a sheath	Leaves not enclosed in a sheath

B Part 2 Conditions Necessary for Proper Germination of Seeds

Suggestions for procedure. Materials for preparing four germination glasses will be necessary, as well as access to a refrigerator. Students should prepare the germination glasses as in Part 1, placing each in the conditions directed. Students should observe each glass daily, noting especially any signs of root or shoot growth.

Interpretation. Moisture, oxygen, and proper temperature are important factors in seed germination.

B Part 3 Seed Viability Testing

Suggestions for procedure. Two pieces of muslin or burlap are required for Part 3, as well as 100 seeds of the same species. The seeds should all be obtained at the same time from the same source, and should be held under the same conditions prior to this study. A "rag-doll tester" should be constructed as directed in the student manual. It is essential that the tester be kept moist, but not excessively wet. The tester should be carefully checked daily for evidence of germination. The number of seeds that have germinated after a reasonable time can be recorded as the percentage of viability.

Interpretation. Lack of stored food in the cotyledons or endosperm, too much warmth and moisture, and improper conditions during dormancy of the seeds.

Suggested References for the Teacher—Unit IV

Books

- Andrew, H. N. *Studies in Paleobotany*. John Wiley & Sons, New York, 1961
- Benson, L. *Plant Classification*. D. C. Heath & Co., Boston, 1957
- Cobb, Boughton. *A Field Guide to the Ferns*. Houghton, Mifflin Co., Boston, 1956
- Conrad, Henry S. *How to Know the Mosses and Liverworts*. William C. Brown Co., Dubuque, Iowa, 1956
- Cronquist, A. *Introductory Botany*. Harper & Row, New York, 1961
- Darrah, W. C. *Principles of Paleobotany*. The Ronald Press Co., New York, 1960
- Editors of TIME, LIFE. *The Forest*. New York, 1964
- Fernald, Merritt and Kinsey, A. C. *Edible Wild Plants of Eastern North America*. Harper and Row, New York, 1958
- Fogg, G. E. *The Growth of Plants*. Penguin Books, Baltimore, 1963
- Foster, A. F., and Gifford, E. M. Jr. *Comparative Morphology of Vascular Plants*. W. H. Freeman & Co., San Francisco, 1959
- Fuller, H. J., and O. Tippe. *College Botany*. Holt, Rinehart & Winston, New York, 1955
- Grabe, Andree V. *Complete Book of House Plants*. Random House, New York, 1958
- Greulach, V. A., and J. E. Adams. *Plants: An Introduction to Modern Botany*. John Wiley & Sons, New York, 1962
- Grimm, William C. *Pocket Guide to the Trees*. Stackpole Co., Harrisburg, Pa., 1958
- Huxley, A. J. *Exotic Plants of the World*. Garden City Books, New York, 1957
- Hylander, C. J. *Plants and Man*. The Blakiston Co., Philadelphia, 1941
- James, W. O. *An Introduction to Plant Physiology*, 6th ed. Oxford University Press., New York, 1963
- Jensen, W. A., and Kavaljian L. G. (eds.). *Plant Biology Today: Advances and Challenges*. Wadsworth Publishing Co., Inc., Belmont, Calif., 1963
- Lee, A. E. *A Laboratory Block: Plant Growth and Development*. D. C. Heath & Co., Boston, 1963
- Lee, A. E., and Heimsch C., *Development and Structure of Plants*. Holt, Rinehart & Winston, New York, 1962
- Miller, Edwin D. *Plant Physiology*. McGraw-Hill Book Co., New York, 1938
- Petrides, George A. *A Field Guide to Trees and Shrubs*. Houghton, Mifflin Co., Boston, 1958
- Popp, H. W., and Grove A. R., *Botany: A Textbook for Colleges*, 3rd ed. McGraw-Hill Book Co., New York, 1960
- Schery, Robert W. *Plants for Man*. Prentice-Hall, Englewood Cliffs, N.J., 1952
- Schultes, R. Z. and Hill, A. F. *Plants and Human Affairs*. Botanical Museum of Harvard University, Cambridge, Mass., 1960
- Selsam, Millicent. *Play with Seeds*. William Morrow and Co., New York, 1957
- Sinnott, E. W., and Wilson K. S., *Botany: Principles and Problems*, 6th ed. McGraw-Hill Book Co., New York, 1963
- Wardlaw, C. W. *Embryogenesis in Plants*. John Wiley & Sons, New York, 1955
- Zim, H. S. *Plants: A Guide to Plant Hobbies*. Harcourt, Brace & World, New York, 1947
- Zim, Herbert S. *Flowers: A Guide to the Familiar American Wildflowers*. Simon and Schuster, New York, 1950

Articles

- Argo, Virgil, "Index to Next Spring's Growth" *Natural History*, January, 1964
- Argo, Virgil, "Insect-Trapping Plants." *Natural History*, March, 1964
- Bassham, J. A., "The Path of Carbon in Photosynthesis." *Scientific American*, June, 1962
- Biale, J. B., "The Ripening of Fruit." *Scientific American*, May, 1954
- Biddulph, Susann and Orlin, "Circulatory System of Plants." *Scientific American*, February, 1959
- Butler, W. L., and Downs, Robert J. "Light and Plant Development." *Scientific American*, December, 1960
- Clevenger, Sarah, "Flower Pigments." *Scientific American*, June, 1964
- "Economic Botany." *The New York Bo-*

- tanical Garden for the Society for Economic Botany*, New York 58, N. Y.
- Gibson, H. Lou, "Cross-Pollination of an Orchid." *Natural History*, April, 1964
- Greulach, V. A., "Plant Movements." *Scientific American*, February, 1955
- Greulach, V. A., "The Rise of Water in Plants." *Scientific American*, March, 1952
- Holter, Heinz, "How Things Get Into Cells," *Scientific American*, September, 1961
- Jacobs, William P., "What Makes Leaves Fall?" *Scientific American*, November, 1955
- Koller, Dov, "Germination." *Scientific American*, April, 1959
- Lawrence, H. Lea, "Man Plant's Return." *Natural History*, May, 1964
- Salisbury, Frank B., "Plant Growth Substances." *Scientific American*, April, 1957
- Salisbury, Frank B., "The Flowering Process." *Scientific American*, April, 1958

UNIT V

BIOLOGY OF THE INVERTEBRATES

In the study of the protozoans, the students observed unicellular organisms. The sponges and coelenterates introduce colonial organisms and simple tissues. Cell specialization and division of labor become important topics for discussion. The student who lives near the seashore will be familiar with many of the members of these lower invertebrate phyla. Others will undoubtedly make use of their knowledge of these organisms on their vacations. Student's interest in these forms of animal life is usually high because they are so different from the more familiar animals.

Flatworms and roundworms introduce parasitism and the problems of controlling parasite infestations. The importance of cleanliness, sewage disposal, meat inspection, and other health measures should be major topics of discussion. The principle of alternate hosts should also be stressed here. The segmented worms, echinoderms, and mollusks illustrate high development of invertebrates and lead to the study of vertebrates in the next unit.

Chapter 30 introduces the arthropods, with emphasis on the crayfish as a characteristic example. In the study of arthropods, the student is introduced to an entirely different form of body structure and one which has been highly successful among living things. Homologous and analogous organs, regeneration, advantages and disadvantages of an exoskeleton, and molting are important topics in this chapter.

Insect study is a major area in most biology courses. The grasshopper is used as a type insect in the study of body structure, life activities, adaptations, and metamorphosis. The study of insects continues with familiar representatives of ten common orders. The closing part of this chapter of the unit deals with the control of insect pests, one of the most vital biological problems we face today.

OUTCOMES

The study of this unit should result in:

1. Understanding of the development of tissues and division of labor in the lower metazoan animals.
2. Knowledge of parasitism among the flatworms and roundworms and understanding of the life cycles and alternate hosts of many of these organisms.
3. Familiarity with health measures involved in the prevention of parasitic worm infestations.
4. Acquaintance with echinoderms and mollusks as complex invertebrates.
5. Understanding of the advantages and limitations of the arthropod plan of structure.
6. Familiarity with common insects: their feeding habits, life histories, and economic importance.

7. Ability to classify insects into orders on the basis of body structure and metamorphosis.
8. Understanding of the principles of analogy, homology, and regeneration as they are illustrated in the arthropods.
9. Acquaintance with the body structure of an insect, such as the grasshopper.
10. Knowledge of the wide variations in the structure and activities of insects.
11. A familiarity with problems caused by insect pests, including carriers and hosts of disease organisms.
12. Acquaintance with insect control measures.

Chapter 27

Sponges and Coelenterates

This chapter introduces multicellular animals, beginning with the sponges and continuing through the coelenterates. It includes three new biological concepts: cell adaptation, division of labor, and cooperative cell existence. The sponge is the first step in this direction, with its two layers of cells and central cavity. The principle of regeneration in the sponge is illustrated in the commercial "seeding" of sponge pieces in specially prepared beds.

Dried or preserved sponges, jellyfish, and pieces of coral should be displayed, if possible. Films, Kodachrome slides, and projected pictures of various living sponges and coelenterates will add much to the interest in this chapter. A discussion of the natural history of these animals is also interesting to pupils.

P. 376, right column: Have dried spicules mounted for use under the microscope or obtained from a supply house already permanently mounted. Dry and clean sponge specimens may be obtained from an auto supply store or department store where they are sold for cleaning purposes. Have a synthetic example on hand for comparison.

P. 381, right column: Have specimens on hand of different species of coral like the fan, brain, and red coral used for jewelry. Films of life under the sea are available in color and show the often brilliant corals which fade when brought out of the sea.

P. 382, right column: *Physalia* and the sea anemone are animals that exhibit symbiosis. They both act as host to fish which are able to swim among their tentacles. The sting of the *Physalia* is very painful.

If many of them are washed ashore after storms, there may be radio warnings to bathers.

The natural history of all these animals includes unusual and fascinating habits which can be seen in films, Kodachrome slides, pictures, and presented in reports.

Suggested Films

First Many-Celled Animals: Sponges (b&w&col, 17 min) EBF
Life on the Coral Reef (b&w&col, 29 min) Ind
Sponges and Coelenterates (col, 28 min) AIBS McGraw-Hill
The Invertebrates (b&w&col, 13½ min) Cor

MAJOR CONCEPTS

1. In multicellular organisms, different cells become specialists in performing certain functions for the benefit of all the cells.
2. The sponge is a sessile animal that obtains food and oxygen and excretes wastes by circulating water through its body.
3. Sponges reproduce both asexually and sexually.
4. Sponges are able to regenerate missing parts.
5. Some sponges live in fresh water although most are marine.
6. The coelenterates are composed of two layers of cells with a jellylike material between.
7. Coelenterates have tentacles and many have stinging-cells.
8. Coelenterates live singly or in colonies.

9. Digestion in the coelenterates is extracellular.
10. Some coelenterates have a life cycle with an alternation of generations.
11. Coelenterates reproduce both asexually and sexually.
12. Some coelenterates, the corals, are reef-builders.
8. Tiny coral polyps secrete cases of lime around their bodies. A group of these form a coral reef. The polyps occupy tiny pores in the reef. Reefs are of three main types: the marginal type forms around an island; the barrier type forms a ring far out in the water; the atoll is a circular reef with an open center.
9. The purple sails and the Portuguese man-of-war are not single animals, but are actually colonies of coelenterates hanging from a float which keeps them near the surface and moving. Some polyps are food-getting, some are reproductive, some are for protection, and some are adapted for feeding. Thus each individual organism performs a special function for the benefit of the colony.

ANSWERS TO QUESTIONS FOR REVIEW (Page 383)

1. When a large number of cells forms an animal body, some of them can become adapted to certain types of activity and can, in turn, depend on other cells which are specialized in other ways. We call this arrangement division of labor.
2. Vertebrates have a backbone which encases the dorsal nerve cord. Animals lacking this structure are classed as invertebrates.
3. Most sponges inhabit shallow seas and tidal pools. However, certain species of both groups are fresh-water forms as, for example, the hydra.
4. The hydra paralyzes its victim with its piercing stinging cells. The tentacles then force the prey into the gastrovascular cavity. An enormous amount of water moves into the sponge through its many pores. This water brings particles of food which are caught by the collar and ingested by the collar cells.
5. Sponges are propagated commercially by sowing pieces of live sponges in special beds. Hydra and other coelenterates, likewise, can be cut into pieces and will regenerate the missing parts.
6. The body of hydra and *Aurelia* consists of two layers, and both possess stinging cells, tentacles, a mouth, and a gastrovascular cavity. The hydra is cylindrical in form; *Aurelia* is umbrella-shaped. The form of *Aurelia* is called a medusa, while that of the hydra is referred to as a polyp.
7. Nematocysts are stinging cells whose function is to paralyze the prey of the coelenterates.

ANSWERS TO APPLYING PRINCIPLES AND CONCEPTS (Page 384)

1. The division of labor principle is applied in modern society when people specialize in certain trades, professions, and other activities. Each specialist does a particular piece of work, but depends on the rest of society for other living requirements. The different cells of a metazoan become specialists in performing certain functions for the benefit of all the cells. Cell specialization enables the organism to survive.
2. Jellyfish lack a circulatory system or any other means of supplying cells lying in the inner layer. Thus the animal must be hollow to allow water to contact cells of the endoderm.
3. Sponge growers cut sponges into pieces and sow them in special sponge beds. Each piece regenerates a new sponge.
4. Exposure of a sponge to air may allow air pockets to form in the pores and interfere with the flow of water through the animal. If the slender flagella of the cells lining the pores and inner cavity are exposed to air, they will dry out quickly and cease circulating water through the animal.
5. The sponge is considered the most primitive of metazoan animals, because it has the least amount of cell

specialization and the most primitive methods of reproduction—budding and regeneration from fragments.

6. Many coelenterates are mobile and are carried by currents or wind blowing over the surface of the wa-

ter. Sessile coelenterates shed gametes and the young are motile. Sponges spread by pieces breaking off, and by gemmules. Warm, shallow waters are most favorable for growth of Porifera and Coelenterata.

Guide to Laboratory Investigations for Chapter 27

INVESTIGATION 27-1

Porifera—The Sponges

Scope of the Investigation Most students have little concept of the makeup of a sponge and may even be surprised to find that it is an animal. This Investigation will acquaint the student with the basic structure of one of the smaller sponges. *Grantia*, more correctly referred to as *Scypha*, was selected because it is readily available at biological supply companies and is relatively inexpensive. Each student or pair of students may be supplied a specimen. Examination of a preserved sponge supplements the discussion of sponges on pp. 375-377 in the text. Of special interest is the position of the sponge at the bottom of the animal kingdom. Sponges have been referred to as “sidelines” in animal development. They are excellent examples of the beginning of division of labor in an organism which is more colonial than multicellular.

Approximate time required Part 1 should be completed in 45-50 minutes. Part 2 will require several days during which examinations are to be made at various intervals.

A Part 1 *Grantia* (Scypha), a Simple Sponge

Suggestions for procedure. Put the specimens in Syracuse watch glasses or small culture dishes (Petri dish covers or bottoms may be used) partially filled with water. Students should be able to locate the incurrent pores and excurrent opening, or osculum, at the top of the sponge. Comparison of the specimen with the calcareous sponge shown in Fig. 27-1-a should aid in identifying these parts. A wall chart of a simple sponge is another valuable aid. Students may have difficulty in seeing cell layers in the sectioned sponge. However, they can determine that *Grantia* has a central cavity and that the body wall consists of two layers.

Student observations—answers to questions.

- (a) Roughened, spiny, and penetrated by numerous pores.
- (b) Calcareous.
- (c) Yes.
- (d) To admit water to the central cavity.
- (e) Water flows out of the sponge through this opening.
- (f) To create water currents and circulate water through the sponge.
- (g) Simple type.
- (h) Water circulating through the sponge supplies food and oxygen and removes cell wastes. The large amount of water required indicates a high level of cell activity.

C Part 2 Regeneration in Sponges

Suggestions for procedure. The observation of regeneration in a sponge is an interesting experience. However, securing a living sponge and sea water may be a problem for schools removed from the coast. The sponge recommended (*Microciona*), can be

obtained by special order from biological supply companies supplying living marine organisms.

Analysis and conclusions. The fact that individual cells dissociated from a sponge body regrouped and reformed the sponge indicates a high degree of capability of regeneration. This capacity also indicates a relatively low degree of cell specialization and interdependence, since the cells survived individually after they were separated.

INVESTIGATION 27-2

The Coelenterates

Scope of the Investigation This Investigation provides the student opportunity to observe two of the coelenterates discussed on pp. 378-381 of the text. *Hydra* was selected for laboratory study because it is easily obtained and cultured in the laboratory. This animal is an excellent example of a coelenterate of the polyp type. The fact that it can be studied in the living condition makes it a good subject for observation of the behavior of a lower invertebrate.

Aurelia is included as an example of a medusa stage of a coelenterate. While many students may never see a living medusa-type jellyfish, they can learn much from close examination of a preserved *Aurelia* floating in a culture dish.

The study of coelenterates has biological significance in introducing animal organisms with two cell layers, a digestive cavity, and a nerve network which coordinates cellular responses. Thus, the coelenterates have reached the tissue level of organization.

Approximate time required Part 1 will require 45-50 minutes if the student makes close observations of the behavior of the hydra and its reactions to external stimuli. Examination of preserved *Aurelia* will require approximately 30-40 minutes. The time required for Part 3 is variable. Daily examinations of regenerating hydras should be made over a period of 14 days or more. These examinations require only a short time and can be made in conjunction with other laboratory work.

A Part 1 Study of a Living Hydra

Suggestions for procedure. Each student or pair of students should be provided with a living hydra. The animals may be placed either in the depressions of culture slides or in small watch glasses. Prior to observation of the hydra under low power of the compound microscope, it is suggested that students examine them with a hand lens or a stereoscopic microscope. This will provide an excellent three-dimensional view of the animal. If the hydra have not been supplied food in the culture, they should seize the *Daphnia* in their tentacles soon after they are placed on the culture slide. Students may observe the paralytic effect of the nematocysts and the entry of *Daphnia* into the gastrovascular cavity. The observation of behavioral responses of hydra to external stimuli will require several animals and culture slide or watch glass preparations.

Student observations—answers to questions.

- (a) No.
- (b) 5-7.
- (c) Elongated with tentacles extended; contracts into a spherical shape with the tentacles withdrawn.
- (d) A contraction of the body wall.

- (e) Tentacles wrap around the *Daphnia* and force it toward the mouth.
- (f) Expansion and contraction of tentacles.
- (g) The hydra changes form.
- (h) Tentacles contract; body contracts; body elongates if basal disk is touched.
- (i) Nerve net.
- (j) Tentacles contract.
- (k) The hydra moves away from the light.
- (l) The hydra moves toward the blue light.
- (m) Red dye moves into the bud.
- (n) Only if mature.
- (o) The bud requires nourishment from the parent.
- (p) Sexually, by gametes.

A Part 2 Study of Aurelia

Suggestions for procedure. Most preserved *Aurelia* supplied for laboratory study vary from 2-4 in. in diameter. Stacking culture dishes (finger bowl dishes) 4½ in. in diameter are excellent for floating the specimens. Students should observe both the dorsal and ventral and probe into the mouth and gastrovascular cavity. The four horseshoe-shaped gonads are clearly visible in the gastrovascular cavity. The four trailing mouth lobes are easily seen on the ventral side. A hand lens will be required to locate the eight sense organs lying in the notches of the marginal bell.

Student observations—answers to questions.

- (a) Eight.
- (b) Gelatinous.
- (c) Provides buoyancy.
- (d) No.
- (e) Radial rather than netted.
- (f) Square.
- (g) Four.
- (h) Lobes are grooved and taper at the end.

B Part 3 Regeneration in Hydra

Suggestions for procedure. Sectioning a hydra to initiate regeneration is a delicate procedure which must be done under magnification. A stereoscopic microscope is best, although a hand lens or stand magnifier may be used. Splitting of the anterior end is the most difficult procedure.

Sectioned hydras must be maintained several days to as long as two weeks for regeneration to occur. They are best maintained in Syracuse watch glasses or small culture dishes which can be placed under a microscope for examination. Pond water or distilled water must be added as needed. The covers placed on the culture dishes should be loose fitting so as to admit air.

Student observations—answers to questions.

- (a) Answers will vary; usually 3-5 days.
- (b) Usually 10-12 days.
- (c) Usually.
- (d) A two-headed hydra bearing two sets of tentacles is formed.

Interpretation. Each section is capable of regenerating all missing parts.

Chapter 28

The Worms

This chapter includes a survey of the three invertebrate phyla of worms. They are presented in order of their complexity. If a living flatworm can be included in this study, the planarian is ideal. This interesting organism represents the free-living flatworms. The fluke, tapeworm, and *Ascaris* represent the parasitic forms. A knowledge of the parasitic forms should be gained by every student. The tapeworm shows degeneration of an organism to a completely parasitic existence in which even digestion is no longer necessary.

Preserved specimens of tapeworms and flukes should be examined if they are available. Living *Planaria* can usually be obtained from any sluggish stream. If water plants are removed and put into an aquarium, *Planaria* can usually be found crawling on the glass the next day.

The segmented worms are much more advanced than those previously studied. Point out to the students that the body of the earthworm not only consists of many cells, but that the cells are specialized and grouped into tissues. The tissues become organs, organs become complicated systems. The body of the earthworm is arranged so that a series of organs performs the fundamental body processes. The study of the external structure and complete dissection of this annelid is performed by students in many biology classes.

P. 385, right column: Although man has bilateral symmetry, both sides are not exactly alike, as one can see when buying shoes or gloves. If a photo is made of each half of the face and duplicated, the results look like two different people. The amoeba is an asymmetrical organism.

P. 386, Fig. 28-2: With the book open, go over the parts of *Planaria* and their functions. Explain the meaning of endoderm, mesoderm, and ectoderm. The top diagram could lead to a discussion of feeding habits and locomotion.

P. 388, right column: Liver flukes are common in countries where raw fish is eaten. Japan consumes vast quantities of raw fish filets called Sashimi.

P. 390, Fig. 28-5: Consult a zoology text and draw on the board with labels: genital pore, vas deferens, vagina, testis, ovary, yolk gland, oviduct, Mehlis' gland, uterus, longitudinal excretory canal, transverse excretory canal. This will emphasize the fact that the tapeworm has no digestive system and consists mostly of reproductive system.

P. 392, left column: The government has inspectors at the large slaughter houses who look for visible parasites. Since the trichina worm is microscopic, it cannot be seen. If these parasites invade heart muscle, the disease is fatal. In other cases steroids are used to alleviate the muscle pain.

P. 395, Fig. 28-11: Discuss the life history of the earthworm, using the open text.

P. 396, left column: Earthworms in pots are undesirable because they disturb the soil too much around house plants. A worm census is taken by running an electric current into the soil. This causes the worms to surface so that the number per square foot can be computed.

P. 396, right column: Heparin from the leech is used as an anticoagulant. The medicinal leech used to travel around in a jar in the doctor's pocket. In fresh water, leeches can be found attached to frogs and turtles. An investigation of their habits would yield interesting information.

Suggested Films

Earthworm Anatomy (b&w&col, 11 min) Ind

Earthworm: Anatomy and Dissection (b&w&col, 11 min) Cor

Flatworms: Platyhelminthes (b&w&col, 16 min) EBF

Parasitism: Parasitic Flatworms (b&w&col, 16 min) EBF

Segmentation: Annelid Worms (b&w&col, 16 min) EBF

Worms (col, 28 min) AIBS McGraw-Hill

MAJOR CONCEPTS

1. The general body form of an organism is called symmetry and is considered

to be of evolutionary significance as it determines an organism's mode of life.

2. The bilateral symmetry of worms is considered to be an advance over the symmetry of the sponges and coelenterates as it is accompanied by cephalization.

3. Cephalization enables the organism to test the environment.

4. Receptors receive stimuli and are concentrated in special organs in the bilaterally symmetrical animal.

5. The brain of a bilateral organism centralizes the communication system for coordination of movement and interpretation of stimuli.

6. Many invertebrates, such as the planarians, are hermaphroditic, although they may also reproduce asexually.

7. A parasite is faced with problems not at all like those of its free-living relatives.

8. The size of a parasite is limited by the size of its host.

9. Intestinal parasites usually have hooks or suckers by which they can cling to the walls of the intestine.

10. Parasitic worms illustrate a reduction or an absence of systems found in their free-living relatives. Thus, the tapeworm is an excellent example of degeneration. The proglottids are essentially masses of reproductive organs.

11. Parasites often have complex life cycles involving more than one host.

12. The most highly developed system in a parasite, as illustrated by the fluke, is the reproductive system.

13. The best control of a parasite, as the fluke, may be to eliminate one of the hosts of the life cycle.

14. Parasites do not immediately kill the host, but usually form a long association.

15. The importance of roundworms is illustrated by the fact that over one third of the human race is infested with roundworms.

16. The importance of good health and cooking practices becomes apparent when one observes the worms.

17. Most segmented worms live in salt water; some live in fresh water; others, including the earthworm, live in the soil.

18. The annelids are organized at the system level of development.

19. The nervous system of the annelids

illustrates a significant evolutionary complexity over that of the planarians.

ANSWERS TO QUESTIONS FOR REVIEW (Pages 397-398)

1. The types of symmetry are classified as spherical, radial, and bilateral. An animal with spherical symmetry has a body that can be divided into two equal parts by any plane passing through the diameter of the body. Radial symmetry is one in which the body has a central disc from which tentacles radiate out like spokes of a wheel. Bilateral symmetry means "two-sided shape," with the sides being symmetrical. Examples of each type in the order named are *Volvox*, sea anemone, and earthworm.
2. Planarians may be divided into several transverse sections, or cut longitudinally, and each section will regenerate the missing parts.
3. The ectoderm, mesoderm, and endoderm of the flatworm are found in all structurally more complex animals and give rise to various organs in these animals.
4. A well-developed nervous system allows the planarian to know what is happening to all the cells of its body. Its eyes perceive light and other nerves cause the animal to react to water currents.
5. Flatworms have three cell layers and greater specialization of cells than sponges and coelenterates.
6. The tapeworm has no digestive system and no means of locomotion.
7. Nematodes are found everywhere: in soil; in plants; in animals; and in lakes, rivers, and oceans.
8. Nematodes have a digestive system composed of a distinct tube, or cylinder. They take food into the mouth, digest it in the food tube, remove usable parts as the food passes along the tube, and eliminate the wastes through an anus.
9. The eggs of *Ascaris* are taken into the human body in contaminated food or water. The eggs hatch within a few hours inside the small

intestine. The larvae bore into the intestinal wall and begin a ten-day journey through the body. They finally reach the blood stream and are carried to the lungs. Then they pass into the air passages, through the throat, and are swallowed into the digestive tube where they grow to maturity in about two and a half months. After the eggs are fertilized, they are surrounded by a thick, rough shell and passed out through the genital pore of the female worm. The eggs then pass out the body of the host with the feces and the cycle continues.

10. The trichina worm is eaten as a cyst in improperly cooked, contaminated pork.
11. The earthworm moves by extending its body, gripping with its setae, then shortening its body by contracting the longitudinal muscles. The posterior setae grip as the anterior end is pushed forward again.
12. Food is drawn into the pharynx, and passes through the esophagus and crop into the gizzard. After being ground up, the food passes through the intestine, where digestion and absorption occur. Indigestible matter is excreted through the anal opening.

ANSWERS TO APPLYING PRINCIPLES AND CONCEPTS (Page 398)

1. Flatworms, roundworms, and segmented worms are similar in name only. The flatworm is a simple organism consisting of three layers of cells. Roundworms have a continuous digestive system with anterior and posterior openings, and, in addition, a circulatory system. Segmented

- worms are far more complex and have fairly well-developed organs.
2. Animals with bilateral symmetry have a definite means of locomotion; those with spherical symmetry usually float on or near the surface of the water. Animals with radial symmetry are often stationary and must obtain food and oxygen from the immediate surroundings.
3. *Ascaris* leaves the small intestine by boring into the intestinal wall, enters the blood stream, then to the lungs. It passes into the air passages and then into the digestive tract. Symptoms of disease are most likely to be present when the larvae pass through the lungs. Inflammation occurs and generalized pneumonia may result. Adults may be so numerous in the intestine as to produce an obstruction, and nervous symptoms may appear as a result of toxic substances released by the worms.
4. The earthworm's nervous system is not composed of a nerve net, but includes both a central and peripheral nervous system. Impulses can go to certain areas without affecting others, unlike in the planaria.
5. Inspection and cooking of meat, especially pork, is one measure in the control of parasitic worms. Since many of these worms live in the human intestine, they may be present in intestinal waste. Thus proper disposal of sewage is an important measure. Hookworm can be avoided by wearing shoes.
6. Loss of digested food in the intestine results from absorption of food by the parasite.
7. Trichina worms have penetrated the muscle tissues and formed cysts, they cannot at that stage be eliminated by the use of purgatives.

Guide to Laboratory Investigations for Chapter 28

INVESTIGATION 28-1

Platyhelminthes—The Flatworms

Scope of the Investigation Several important biological concepts are developed in this Investigation. The three layers of cells composing a flatworm and the presence

of well-developed organs represent a station of biological development above that of the coelenterates. The study of flatworms includes both a free-living and a parasitic form. By contrasting Planaria and a tapeworm the student will discover the degenerative effect of parasitic life.

Planaria has been used extensively for regeneration experiments. Part 3 includes a series of procedures for demonstrating this capability. Part 4 introduces light factors as influences on the rate of regeneration in a research investigation.

The Parts of this Investigation correlate with the discussion of flatworms on pages 386-390 of the text.

Approximate time required Examination of the structure and behavior of living Planaria in Part 1 will require 40-50 minutes. Additional time may be necessary to complete the suggested environmental stimuli and observation of responses. An additional 40-50 min. will be necessary to complete the study of longitudinal and cross sections. Examination of a preserved tapeworm in Part 2 may be correlated with this study. The time required for completion of the regeneration procedures in Part 3 is variable. Sectioning may be done in a short time. Daily observations should be made for several weeks while other Investigations are in progress. Part 4 is a research problem which will require several weeks.

A Part 1 Planaria—The “Cross-eyed Worm”

Suggestions for procedure. Planaria may be collected from local streams, as suggested. If this is done, the animals should be cultured in the laboratory several weeks in advance. In most cases, it is advisable to obtain Planaria with directions for maintaining cultures from a biological supply company. Large black worms are usually available.

Students should have no difficulty in seeing the structures of Planaria with a hand lens, stand magnifier, or stereoscopic microscope. The flashlight used to demonstrate light responses should provide a small beam of light which can be directed on various regions of the animal. A pencil flashlight is good. If a larger flashlight is used, the lens should be covered with a shield containing a small circular opening. This can be made of cardboard.

Prepared slides, available at biological supply companies, are required for the study of longitudinal and cross sections of Planaria.

Student observations—answers to questions.

- (a) Smooth and pigmented.
- (b) Gliding motion; extension and contraction.
- (c) Usually turns toward the current.
- (d) Contracts rapidly.
- (e) Contracts more slowly.
- (f) Moves away from the light.
- (g) Usually no reaction.
- (h) Moves into the darkened area.
- (i) Moves toward the liver.
- (j) Moves away.
- (k) Covered with cilia.

A Part 2 The Tapeworm

Suggestions for procedure. Since students do not make a detailed study of the tapeworm, preserved specimens in museum jars will be sufficient. Fig. 28-1-a may also be used to study gross structure. If a chart showing the life history of a tapeworm is available, it may also be used to emphasize health aspects of the tapeworm. This is an important part of the study of parasitic flatworms.

Student observations—answers to questions.

- (a) Attachment to the intestine of the host.
- (b) No.
- (c) Digested food is absorbed from the host.
- (d) By consuming egg cases or a cyst in a muscle.
- (e) Lacks a mouth, digestive system, nervous system, and sense organs.
- (f) Reproductive.

B Part 3 Regeneration in Planaria

Suggestions for procedure. This Part is suited to individual investigation or a demonstration for the class. It may be necessary to make several attempts before the experiments are successful. Fresh water must be supplied in the cultures over a period of several weeks while regeneration is occurring. Diagrams for sectioning Planaria are shown in Fig. 28-1-b. Additional information may be found in more advanced references and articles in periodicals.

Student observations—answers to questions.

- (a) Those nearest the anterior end.
- (b) Those nearest the posterior end.
- (c) It is more rapid; animals are more like the original Planaria.
- (d) The planarian is small; form may be modified; color is usually lacking in early stages.
- (e) No.
- (f) Those produced from posterior sections.
- (g) Tissue in posterior sections lacks the property of differentiating and forming head structures (auricles, eye spots, etc.).
- (h) By grafting two anterior or posterior sections.

Interpretation. The head region regenerates most rapidly and completely. The capacity to regenerate decreases from the anterior end toward the posterior end and may be lacking entirely in the posterior region.

C Part 4 The Effect of Colored Light on Regeneration in Planarians

Suggestions for procedure. This Part outlines a research project for an advanced student. The investigator must be familiar with techniques for sectioning the animals and the process of regeneration. He must be able to detect both the rate and the degree of regeneration occurring in the various light conditions.

Analysis and conclusions. Results are not always predictable. However, the investigator will probably find that the wave lengths or red light tend to stimulate regeneration. Other wavelengths usually have little or no more effect than ordinary diffuse white light.

INVESTIGATION 28-2**Nematoda—The Roundworms**

Scope of the Investigation This Investigation includes a study of three well-known parasitic roundworms. Since parasitic roundworms are serious health problems both in man and in animals, the examination of preserved specimens and prepared slides to determine their structure and adaptations is supplemented with questions relating to life histories, mode of entry into a host organism, and site of infestations. This Investigation supplements the discussion of parasitic roundworms on pp. 390-392 of the text.

Approximate time required All three Parts should be completed in 45-50 minutes. Time may be saved by setting up demonstration microscopes in making their examinations.

A Part 1 Ascaris

Suggestions for procedure. Preserved *Ascaris* is available at biological supply companies. Females are usually used because they are larger than males. However, shipments usually include several males for comparison with the females. *Ascaris lumbricoides*, a parasite in man and swine, is usually supplied. Often a veterinarian can supply roundworms similar to *Ascaris* (*Toxascaris* and *Toxocara*) from dogs which have been wormed. A chart showing the detailed anatomy of *Ascaris* and Fig. 28-2-a will aid the student in his dissection.

Student observations—answers to questions.

- (a) No.
- (b) No.
- (c) Longitudinally.
- (d) No.
- (e) A thickening on each side (containing an excretory canal)
- (f) Females are larger; the posterior end of the male is recurved.
- (g) Eggs are excreted with the feces and are consumed by an animal (hog); eggs hatch in the small intestine; larvae burrow into blood vessels and are carried to the lungs; larvae pass up the trachea to the throat and are swallowed; in the small intestine, they mature, mate, and the female lays eggs.
- (h) The digestive system consists only of a longitudinal tube and does not perform a digestive function; sense organs are lacking.

A Part 2 The Hookworm

Suggestions for procedure. Because it is very small, the hookworm (*Necator*) is best studied from a whole mount on a microscope slide. Low power is sufficient magnification to see the details of its structure. Locate, if possible, the sharp plates in the mouth cavity by which the hookworm grasps the lining of the intestine and sucks blood and tissue fluids. A chart showing details of the worm and enlargement of the mouth is a valuable teaching aid.

Student observations—answers to questions.

- (a) Usually through the skin of the feet.
- (b) The hookworm damages the lining of the intestine and perforates small blood vessels causing loss of blood. This results in anemia and general lack of physical energy.
- (c) By wearing shoes; also proper sewage disposal and other sanitary measures.
- (d) In the Southeast, especially in rural areas.

A Part 3 Trichina Worm

Suggestions for procedure. A mature trichina worm (*Trichinella*) is less than 1/25 in. and should be studied as a whole mount on a microscope slide. However, biological supply companies can furnish pieces of muscle containing both mature worms and cysts as well as preserved worms for mounting. Fig. 28-2-b shows a trichina cyst in a muscle, since this stage is difficult to demonstrate. A chart of trichina is a valuable supplementary teaching aid. Trichinosis is a serious disease in man. Therefore, stress should be given to preventive measures.

Student observations—answers to questions.

- (a) Usually the hog.
- (b) Muscles.
- (c) As a muscle cyst.
- (d) By the wall of the cyst.
- (e) By inspection of meat, thorough cooking, and sanitation.

INVESTIGATION 28-3**The Earthworm—A Representative Annelid**

Scope of the Investigation The earthworm is a favorite subject for the study of invertebrate anatomy, physiology, and behavior in many biology courses. Seven organ systems are well-developed in this representative annelid. A dissection, as outlined in Section 2 of Part 1, will reveal these organs clearly. The earthworm is discussed in detail on pp. 393-396 of the text. Investigation of the external and internal structure and observation of behavior and reactions of the worm to external stimuli will have more meaning if the student has this information prior to his laboratory study.

Approximate time required Examination of the external structures and dissection of the earthworm in Part 1 will require 45-50 minutes. The dissection should be completed the same day as started to avoid drying out. The study of responses of the worm to external stimuli in Part 2 should be completed in 45-50 minutes. Three weeks is the suggested time for Part 3. Preparation of the sections will require only a few minutes. Daily observations and measurements of the sections for evidence of regeneration can be done while other laboratory work is in progress.

A Part 1 Structure of the Earthworm

Suggestions for procedure. The earthworms used in this Part may be either freshly preserved or specially prepared and extended specimens available at biological supply companies. The commercially prepared specimens are hardened in preservative and are therefore more easily dissected.

Examination of the external structures in Section 1 will require a hand lens. Either a living or preserved earthworm may be used. The dissection in Section 2 may be made without magnification, although a hand lens, stand magnifier, or stereoscopic microscope will be needed to see many of the organs clearly. Since most of the organs lie in the anterior region of the worm, the incision is started one inch behind the clitellum and continued forward to the anterior end. The incision is made to the left of the mid-dorsal line to avoid cutting the dorsal blood vessel. As the body wall is opened, it should be pinned back on both sides. Place the pins about $\frac{1}{2}$ in. apart and at an angle so that they do not obstruct the working area.

Many teachers supplement the dissection of preserved earthworms with a demonstration section of an anesthetized worm. This worm, viewed under a stand magnifier or stereoscopic microscope, will permit students to see the pulsating aortic arches. Worms used for this demonstration may be anesthetized in 70% alcohol. The worms should be removed as soon as movement ceases. Worms may also be anesthetized in a closed container, using a piece of cotton saturated with ether or chloroform.

Examination of a cross section of an earthworm is suggested at the end of Section 2. A prepared microscope slide is required in this study. It may be necessary to delay this examination until another laboratory period.

Student observations—answers to questions.

- (a) Smooth on the dorsal surface; bristles on lateral and ventral surfaces.
- (b) Four pairs.

- (c) Beneath the cuticle (in small sacs in the body wall).
- (d) Grip the soil.
- (e) The anterior end is more rounded and darker in color.
- (f) Elimination of intestinal content.
- (g) Two on each segment except the first three and the last.
- (h) Excretion of metabolic wastes.
- (i) Secrete the cocoon.
- (j) The posterior end is pulled toward the anterior end.
- (k) Muscular contraction.
- (l) Drawing materials into the mouth by suction.
- (m) Joins the pharynx and the crop.
- (n) Storage and softening of ingested materials.
- (o) Mechanical grinding.
- (p) Each worm forms both eggs and sperm. Sperm are produced in the testes, stored in the seminal vesicles, and transferred to the seminal receptacles of another worm via the male pores. Eggs are produced in the ovaries and pass through the female pores into a slime ring formed by the clitellum. As the slime ring passes over the male pores in segments 10 and 9, sperm are deposited and fertilization occurs.
- (q) Pumping of blood from the dorsal to ventral blood vessels.
- (r) Blood is pumped through the aortic arches to the ventral blood vessel which extends to the posterior end beneath the digestive tract. The ventral blood vessel branches into a series of transverse vessels which lead to all parts of the body. Blood from these vessels flows to the dorsal blood vessel which returns to the aortic arches.
- (s) By tubes leading to small pores.
- (t) Kidney.
- (u) To muscles.
- (v) Control movements.
- (w) Through the skin.

A Part 2 Activity and Responses of the Earthworm

Suggestions for procedure. Living earthworms used in this Part may be supplied by members of the class or purchased from a local bait store or a biological supply company. It is important that the worm be placed on a surface into which it may extend its setae for traction. This may be a moistened paper towel, as suggested, or a layer of sand or soil in a dissecting pan. If a living worm was not used in Part 1, this is a good time to observe movements of the segments and body wall as the worm crawls in response to external stimuli.

Student observations—answers to questions.

- (a) As the worm moves forward, the body extends and the segments are constricted. The anterior end remains stationary, because of gripping by the setae. The free posterior end moves toward the anterior end. This causes increase in diameter of the segments.
- (b) The circular muscles contract the segments and extend the worm. Contraction of the longitudinal muscles shortens the body and expands the segments.
- (c) Toward the anterior end.
- (d) No.
- (e) The body shortens and the worm moves away.
- (f) Anterior end.
- (g) The worm moves away from light.
- (h) Light would dry out the body surface and prevent respiration.
- (i) The worm moves away. However, the response is usually not as rapid as that when light strikes the anterior end.

- (j) Red light attracts the worm.
- (k) No.
- (l) Variations in wavelengths of light seem to have different effects on nerve endings.
- (m) The worm moves toward the celery leaves.
- (n) The worm begins to burrow into the soil.
- (o) Loosening and transportation of soil.

C Part 3 Regeneration in the Earthworm

Suggestions for procedure. Success in this experiment cannot be predicted. Many of the sections will probably die. However, the anterior end is the most likely to live and regenerate a portion of a tail region. Water in each of the Syracuse watch glasses should be changed daily.

Analysis and conclusions. Regeneration in the earthworm seems to be limited by the number of segments removed. The worm cannot regenerate more than five anterior segments. If 15 or more anterior segments are removed, the worm cannot regenerate a head. A posterior section usually regenerates a posterior end rather than an anterior end.

Chapter 29

Mollusks and Echinoderms

The survey of invertebrates continues with the study of the clam and starfish. Mussels, clams, snails, and squids do not appear to have much in common, but further study will show the student that several structures are possessed by all. This chapter presents an excellent opportunity to review some of the basic concepts in biology—the basis of classification and the adaptations of an organism both in body structure and physiology. Emphasize the fact that the clam has changed little since early times. It survived because of the protective shell and its adaptations for living in a changing environment. There are a great many species of mollusks, and they are found on land and in both fresh and salt water.

If available, the fresh-water mussel is a good specimen to use because it can be dissected without much difficulty. Clams may be purchased at certain markets. A living clam can be housed in an aquarium containing a deep layer of sand. Students can observe the flow of water through the siphons and the action of the foot in pulling the clam through the sand. Aquatic snails thrive in a jar of water containing water plants. These snails will eat lettuce dropped

into the jar. A woodland terrarium should be used to house a supply of land snails and slugs. Their terrestrial adaptations should be compared to structures in freshwater and marine relatives.

Because of the tendency of the snail to stay still for long periods, the study of a snail's movement may be a valuable lesson in patience. The squid and octopus are good subjects for special reports. A shell collection is a good mollusk project, and shell identification books are available in libraries.

Various echinoderms may be studied from dried or preserved specimens, but fresh specimens are preferable when available. Students living on the coast are fortunate as they can observe the movement of these animals by the tube feet. Kodachromes and films will show this mode of movement to the students.

P. 399, Fig. 29-1: Between the green lines of the diagram lie the esophagus, stomach, and anus of the animal, and the hairlike structure at the top of the larva is the apical organ.

P. 400, Fig. 29-3: The shells of many species are of special interest, e.g., the shells that provide Tyrian purple (of his-

torical importance), buttons, and jewelry. Edible mollusks like the whelk, abalone, and some land species can be bought fresh in large cities. Included with canned snails are the shells into which the animal is put to be broiled.

P. 404, left column: Fresh squid are used as food. Young octopus is sold dried or canned. The cuttlebone of squid can be obtained in pet stores where it is sold for canaries and parakeets. Both squid and octopus have unusual habits like sending out a cloud of "ink" in the water when disturbed.

P. 406, Fig. 29-11: Films will show the unique method of locomotion using a water-vascular system. Both young starfish and sand dollars are used for jewelry when sprayed with gold paint. Some starfish relatives have as many as 20 arms.

Suggested Films

Adaptive Radiation: Mollusks (b&w&col, 18 min) EBF

Echinoderms (col, 28 min) AIBS McGraw-Hill

Mollusks: A Story of Adaptation (col, 28 min) AIBS McGraw-Hill

On the Rocks (b&w&col, 29 min) Ind

The Life Cycle (b&w&col, 29 min) Ind

MAJOR CONCEPTS

1. Similar larvae are considered to indicate a close relationship or similar evolutionary development from a common ancestor. This is illustrated by the diversity in the molluscan group.
2. Mollusks inhabit fresh-water, marine, and terrestrial environments.
3. Fossil mollusks have furnished the geologist with important data for dating and reconstructing changes that have occurred on the earth's surface.
4. The general body plan of an adult mollusk consists of a head, foot, and visceral hump.
5. Bivalves have a well-developed nervous system with several large ganglia.
6. Bivalves illustrate a mucous-ciliary method of feeding.
7. Some mollusks live in symbiosis with other organisms.
8. The gastropod has a browsing way of life.

9. Most cephalopods are fast swimmers and predatory carnivores.

10. All echinoderms are marine, and have a hard, radially symmetrical body covered with spines.

11. A water-vascular system and tube feet are characteristic of the echinoderms.

12. The dipleurula larvae of the echinoderms are similar to those of some of the lower chordates, thus suggesting a possible relationship.

13. A phylogenetic tree represents regularities which may be useful in picturing animal evolution. It includes relationships based on incomplete fossil records, morphological similarities of both larvae and adults, physiological similarities, and imagination.

ANSWERS TO QUESTIONS FOR REVIEW (Page 409)

1. The type of shell, if present, is the basis of dividing the mollusks into classes.
2. Soft body, foot, and mantle.
3. Water containing food enters the ventral siphon of the clams, enters the mantle cavity and passes over the gills. The food sticks to the thin mucous layer on the gills. Cilia beat forward and carry the mucous strands and food to the mouth. From the mouth, food enters the esophagus, passes to the stomach and then to the digestive gland.
4. Pearly layer, prismatic layer, and horny layer.
5. A pearl forms in an oyster when an encysted worm or grain of sand lodges between the mantle and the shell. Gem pearls are produced only in the pearl oyster of the Pacific and Indian Oceans.
6. In contrast to the gastropods, the cephalopods are generally without outer shells. The body is covered by a thick, toughened mantle and the foot is divided into eight or more tentacles with suction cups.
7. A hard, shell-like body which is radially symmetrical and covered with spines.
8. The starfish can grip an object with its tube feet and bend its arms to

- produce movement. It also raises its body and "walks" slowly on its arms.
9. The water-vascular system of the starfish provides the suction of the tube feet which exerts a steady pull used in opening the shells of mollusks.
 2. Deposits of mollusk shells indicate the locations of prehistoric seas.
 3. Mollusks have been used as food, for money, eating utensils, jewelry, buttons, dyes, tools, and weapons. Garden snails and slugs do great damage to plants with their rasping radulas.
 4. The principle mineral substance present in mollusk shells is calcium carbonate. Other calcium compounds may be present. Marine mollusks may also contain other minerals, including iodine salts.
 5. Fossil records and morphological similarities of both larvae and adults.

ANSWERS TO APPLYING PRINCIPLES AND CONCEPTS (Page 409)

1. The larvae of the mollusks and the annelids are very similar. They are called trochophores.

Guide to Laboratory Investigations for Chapter 29

INVESTIGATION 29-1

Mollusca—The Soft-Bodied Animals

Scope of the Investigation The Parts of this Investigation, correlating with pp. 399-404 of the text, include a comparison of diverse mollusk types and a more detailed study of the freshwater clam and the snail. The fact that they are widely distributed in marine, fresh-water, and terrestrial environments is indication that they are biologically successful. The student will discover a diversity in form yet a basic similarity in all mollusks in his comparative studies in this Investigation.

Approximate time required Part 1 can usually be completed in 45-50 minutes. The time for Part 2 is variable, but is usually 45-50 minutes. Part 3 will also require about 45-50 minutes. The teacher may save time by conducting these two Parts simultaneously, with some of the students dissecting the clam while others are dissecting the snail. All students may then examine both dissections. Part 4 cannot be geared to a time schedule. Much of this study may be conducted outside of class over a period of several days.

A Part 1 Characteristics of the Mollusks

Suggestions for procedure. Preserved specimens of all of the mollusk types selected are available at biological supply companies. Six or eight specimens of each type will supply the average-sized class since students may exchange specimens. Fig. 29-1-a will assist the student in his study. Charts of mollusk types, display mounts, and projection slides will add to the study.

A Part 2 Anatomy of the Clam

Suggestions for procedure. Preserved fresh-water clams are available at biological supply companies or may be collected and preserved locally. Specimens 5 inches or more in length are preferred. Commercially prepared clams may be pegged to improve preservation and permit the student to cut the adductor muscles and open the shells without damage to the soft body. Students may work in pairs or small groups in making the dissection. A dissected clam for student labeling is provided in Fig 29-1-b as a means of saving time.

Charts and models of a clam dissection are valuable teaching aids. Since the anatomy of the clam is unique, the student will require direction before he starts his dissection and as the work progresses. However, he should draw his own conclusions regarding the relation of organs and systems to the clam's way of life.

If a living clam can be housed in an aquarium with a deep layer of sand, students can observe the excurrent and incurrent openings and the extended hatchet-shaped foot which may be seen by extracting the animal quickly.

Student observations—answers to questions.

- (a) Strengthens the hinge and prevents longitudinal sliding of the valves and tearing of the elastic ligament.
- (b) To prevent irritation of the mantle.

A Part 3 Study of the Snail

Suggestions for procedure. Both living and preserved snails are required in this Part. Living native land snails (*Polygyra*) are available at biological supply companies or may be collected locally. The preserved specimens may be land snails or fresh-water species. Large land snails including *Helix*, a European form, and *Achatina*, an African form, are ideal for a demonstration dissection.

A chart showing external and internal structures of a snail, display mounts, lantern slides, and shells of other gastropods such as the limpet (*Achmaea*), conch (*Busycon*), whelk (*Buccinum*), and periwinkle (*Littorina*) will add to the study.

Student observations—answers to questions.

- (a) By a gliding motion.
- (b) The tentacle is retracted.

B Part 4 A Snail's Pace

Suggestions for procedure. Since this Part requires time-consuming measurements of the movement of snails under varying conditions, it is best conducted by an individual student or an investigating team. Temperature variations should demonstrate environmental influence on the rate of metabolic activity of the snail as evidenced by variations in the rate of locomotion.

Living common land snails are good subjects for the experiment. All snails used should be the same species and about the same size.

Student observations—answers to questions.

- (a) Answers will vary. However, a snail usually moves at a rate of about two inches (50 mm) per minute or about 10 feet an hour at room temperature. At this rate, it would require 528 hours, or 22 days, for the snail to travel a mile, if it moved continuously.
- (b) 15-20 minutes.
- (c) Yes.
- (d) The rate of movement decreases as the temperature is lowered.
- (e) Yes.
- (f) The rate of movement increases as the temperature increases.

Interpretation. The snail moves by secreting a layer of mucus on which the foot glides by undulating muscular contractions. Both the secretion of mucus and the muscular activity vary with the rate of metabolic activity. This activity is in turn influenced by external temperature.

Chapter 30

The Arthropods

This is the first of three chapters dealing with arthropods, the largest and most important group of invertebrates. The arthropods differ from previous phyla in a number of structural features, the most noticeable one being the presence of jointed appendages. Their appendages vary with the organism and are used in many different ways by these animals.

We selected the crayfish as a type arthropod for study. In addition to illustrating the exoskeleton, segmented body, and jointed appendages, characteristics of arthropods, the crayfish is a classic example of homology of appendages. This principle should be emphasized in discussing the various appendages and their use to the crayfish. This is an ideal time to discuss regeneration as well.

The lobster, crab, and shrimp are discussed briefly in the section dealing with crustaceans. If possible, display museum specimens of these arthropods and include special reports on the economic uses of them. If time permits, the collection, culturing, and examination of *Daphnia*, *Cyclops*, fairy shrimp, and other minute crustaceans is interesting. Several of these organisms are shown in Fig. 30-5, page 417 of the text.

Centipedes, millepedes, and spiders should be maintained in jars or Petri dishes temporarily so they can be observed closely during the work on this chapter. Many pictures are available showing spiders and their webs. Spinning may provide the topic for discussion or reports.

P. 414: Live specimens of crayfish may be kept for observing eating habits. They like ground raw beef, but be sure none is left in the water when the animals are finished eating. If a harmless dye is placed in the front or the rear of the animal, the direction of the current set up by the animal's movements can be seen. This current helps in respiration. Observe the first pair of swimmerets of the male. They are long and clawlike whereas those of the female are thin and threadlike. The cup for collecting sperm is also visible on the lower

side of the female's body. Delayed fertilization is characteristic of some animals even more complex than the crayfish.

P. 415, left column: The chamber holds moisture and enables the crayfish to migrate to other ponds in summer drought.

P. 416, left column: Crayfish exhibit autonomy. They may be found with one extremely small cheliped and one of normal size. In Europe crayfish are often eaten.

P. 416, right column: Crabs along with seaweed are available in season from fish stores. Some have interesting habits, such as the fiddler crab which does a courtship dance. Shrimp may also be obtained at a fish market although they are usually headless. Extremely small species are sold in cans. They make good class samples.

P. 417, Fig. 30-5: *Daphnia*, *Cyclops*, and fairy shrimp can be obtained from stores specializing in tropical fish. Ponds may also yield good specimens for culture in the laboratory.

Suggested Films

Arthropods: Insects and Their Relatives (b&w&col, 11 min) Cor

Crayfish Anatomy (b&w&col, 11 min) Ind

Crayfish: Life Cycle (b&w&col, 11 min) Cor

Crustacea and Their Allies (col, 28 min) AIBS McGraw-Hill

MAJOR CONCEPTS

1. From the standpoint of numbers, the arthropods are considered the most successful group of animals.
2. Jointed appendages, a chitinous exoskeleton comprising a segmented body with dorsal heart and ventral nervous system, and muscles in groups are characteristics that separate the arthropods from other animals.
3. The segmented body of an arthropod suggests a relationship to the annelids.
4. The increasing complexity of the arthropod sense organs allows for coordinated responses to the environment, which is a factor contributing to the success of the group.

5. The hard exoskeleton of the arthropods is a protective advantage over the soft cuticle of the worm, but it is also a size-limiting factor.
6. Growth of an animal with an exoskeleton can only occur by molting.
7. Arthropods live in fresh water, marine, and terrestrial environments.
8. Arthropods are of importance to man as food, destroyers of crops, stored food, clothing, as pests, and as carriers of disease.

ANSWERS TO QUESTIONS FOR REVIEW (Page 422)

1. An exoskeleton, segmented body, and jointed appendages.
2. a. Crustacea (crayfish); b. Chilopoda (centipede); c. Diplopoda (millipede); d. Arachnida (spider); e. Insecta (grasshopper).
3. Both have a segmented body.
4. The exoskeleton gives excellent protection. However, its weight in proportion to the size of the body is a handicap and probably has limited the arthropods in size. Freedom of motion is limited in many arthropods.
5. Water enters the gill chamber at the rear edge of the cephalothorax, passes under the carapace, through the gill chambers on the sides, and out through openings at the front of the gill chamber on the lower side.
6. Crayfish respond to touch (antennae), light (compound eyes), and hearing (poorly developed ear sacs).
7. A centipede has many similar segments, each bearing a pair of legs. Many species inject poison into bites through their powerful mandibles. In contrast, the millipede has

- many similar segments, each bearing two pairs of very short legs. None of the millepedes inject poison when they bite.
8. The principle food of spiders is insects. All spiders inject poison into a bite. This has led many people to believe that all spiders are dangerous, whereas only a few species are dangerous to man.
9. Ballooning is a method by which some spiders spread to new habitats. As the young are dispersed by the wind, many meet death by drowning or by landing in other unsuitable environments. However, in a very short time, many reach favorable areas far from their origin. Thus, the species has spread and their chances of survival are better than in an overcrowded limited area.
10. In addition to spiders, the class Arachnida includes scorpions, ticks, mites, and daddy longlegs.

ANSWERS TO APPLYING PRINCIPLES AND CONCEPTS (Page 422)

1. The armored exoskeleton of an animal like the crayfish reduces its sense of touch on the body surface. However, sensitive antennae assume this function.
2. Crayfish living in water flowing through granite, because the exoskeleton contains a great deal of calcium, and limestone is calcium carbonate.
3. The young crayfish are protected from enemies, are provided with fresh water, and are given a proper habitat.
4. Barnacles, if they are numerous, may make the vessel difficult to steer.

Guide to Laboratory Investigations for Chapter 30

INVESTIGATION 30-1

The Crustaceans

Scope of the Investigation The crayfish is used as a representative crustacean because it is familiar to many students and easily obtained for study. The arthropods logically follow the segmented worms in a systematic study of organisms. The seg-

mented body structure of the annelid is carried to a higher level of specialization in the arthropod. The crayfish, representing a higher type of arthropod, has greatly modified appendages growing from nearly all of its segments. This provides an excellent illustration of homology.

The laboratory study in this Investigation correlates with the discussion on pages 410-415 of the text. The student will examine the external structures of a crayfish, observe the behavior and reactions of a living specimen, and explore its internal organs and systems in a dissection. In addition, the behavior of two terrestrial isopods, is studied.

Daphnia is the subject of a suggested research investigation to determine the effect of temperature on the rate of heart beat. Data obtained in this study will have many biological applications in the study of other organisms and the relation of their physiological activities to environmental conditions.

Approximate time required Observation of the external structures of the crayfish and completion of the drawings of certain appendages will require a minimum of 45-50 minutes. Observation of the activities and responses of the crayfish in Part 2 can usually be completed in 30-40 minutes. Except for the first experiment, which will require observation into the next day, Part 3 will require about 30 minutes. The dissection and drawing in Part 3 will require at least 90 minutes. The time necessary to complete Part 5 will vary with the technique of the student. Since this is a research project, it is recommended that the experiment be conducted outside of regular class time.

A Part 1 External Anatomy of the Crayfish

Suggestions for procedure. The preserved crayfish used in this Part will also be used for the dissection in Part 3. Specimens may be supplied by members of the class in many areas. However, large crayfish, available at biological supply companies, are preferred by many teachers.

The teacher should stress structural and functional modifications of the appendages as an illustration of homology. Each student should determine the sex of his specimen. Certain of the crayfish used in a class may illustrate regeneration of a lost or injured appendage. For example, such a specimen may have chelipeds of unequal size.

As a part of the study, the teacher may use additional crustaceans for comparison with the crayfish. The American lobster (*Homarus*), blue crab (*Callinectes*), hermit crab (*Parurus*) and shrimp (*Crangon*) are good supplementary materials.

Student observations—answers to questions.

- (a) Seven, including the telson as a segment.
- (b) Hexagonal.
- (c) Both are segmented; the antennules are branched.
- (d) The mandibles move from side to side; the maxillae move freely in all directions.
- (e) Small, and are composed of only two segments.
- (f) They are smaller (both second and third maxillipeds are composed of five segments).
- (g) Do not terminate in a pincer or single "claw."
- (h) Usually, unless one has been regenerated.
- (i) They may differ in size.
- (j) The second and third pair terminate in pincers. The fourth and fifth terminate in a single "claw."
- (k) Answers will vary.

A Part 2 Activity and Responses of the Crayfish

Suggestions for procedure. Living crayfish can usually be supplied locally. If students cannot bring them in, bait companies may stock them. Otherwise, they are available

at biological supply companies at most seasons of the year. Small aquaria (1 or 2 gallon) are ideal for observing the activities of living crayfish. Six-inch battery jars or large culture dishes may also be used. Crayfish in a large room aquarium will provide additional opportunity for observing behavior, feeding habits, locomotion, and other activities.

Several external stimuli are suggested in this Part. Students may devise other methods of observing reactions of the living crayfish.

Student observations—answers to questions.

- (a) Answers will vary. Usually, the crayfish seeks protection under a rock or in a corner, facing the possible danger.
- (b) Usually forward, raised on walking legs with abdomen extended.
- (c) Moves antennae; usually backs away.
- (d) Mouthparts; hairlike projections on body and legs.
- (e) Moves away from light.
- (f) Usually no reaction.
- (g) The compound eyes are the light receptors.
- (h) Mouthparts begin to move quickly.
- (i) The crayfish usually becomes very excited and may try to climb out of the container.
- (j) Positive to sugar; negative to vinegar.
- (k) Posterior to anterior through gill chamber.
- (l) Rapid movement of the gill bailers, outgrowths of the second maxillae.
- (m) Usually.
- (n) By means of the chelipeds.
- (o) Statocysts (balance organs) at the basal segments of the antennules.
- (p) Grains of sand (statoliths) move against sensory hairs in the statocysts.

A Part 3 Internal Anatomy of the Crayfish

Suggestions for procedure. Before starting the dissection of a crayfish, the student should read the directions in this Part carefully. A wall chart showing the internal organs may also be used to acquaint the student with the organs he will find in his dissection. This preliminary study is important because the structure and location of the organs in a crayfish are different from those of vertebrates with which the student is probably more familiar.

The drawing in which the student records his observations need not be elaborate. Only the base of the appendages visible from the dorsal side need be shown for the purpose of orienting the organs in the body.

B Part 4 Behavior of Terrestrial Crustaceans

Suggestions for procedure. The common sowbug (*Porcellio laevis*) and pillbug (*Armadillidium vulgare*), collectively known as isopods, are easy to collect and to maintain in a school laboratory. They live under stones and boards, under planks and floorboards of greenhouses, in rotten stumps and logs, and under layers of leaf mulch in woodlands. They can be kept in a terrarium or even in pint jars half-filled with rich, moist mulch. Containers should be kept in subdued light away from heat. Occasionally place potato slices or carrot slices on top of the mulch. These animals like to gather beneath an edible object. The vegetable slices also help to maintain moisture.

The ability to roll into a ball when disturbed distinguishes pillbugs from sowbugs. If students have already learned that crustaceans are gill-breathing arthropods, they may ask why these animals do not live in water. You can use this opportunity to show that modifications and exceptions exist in body plans and functions. These animals do breathe by means of gills, but the gills are modified for air-breathing. They are protected by platelike abdominal extensions and must be kept moist at all times.

The experiments are designed to demonstrate certain requirements and oriented responses of the animals. Oriented responses which involve locomotion, formerly known as tropisms, are now called taxes. Although these isopods can exist for several days without food, lack of moisture for even a few hours will kill them, as shown in the first experiment. With appropriate equipment one can subject them to air of known degrees of humidity and determine survival time and behavior. Sowbugs and pillbugs are nocturnal, and the second experiment shows that they avoid light (negative phototaxis). Animals placed in bright light will congregate under the dark paper; those in subdued light will roam all around the container. This action can be shown to an entire class if an opaque projector is available. These animals also avoid heat (negatively thermotactic). When one side of the dish is heated in the third experiment the animals will move from that side to the one which is unheated.

These experiments provide the teacher with an opportunity to emphasize that the behavior of these animals is adaptive. We tend to emphasize structural adaptations, but adaptations may also be physiological, biochemical, or behavioral. The animals move from unfavorable into favorable habitats, both in the experiments and in their natural habitats. You may have your students verify their conclusions by allowing them to take a short field trip to locate some of these animals in their natural habitats. If this is not feasible, make it a home assignment. Ask for a written report of their findings. In their natural habitat sowbugs and pillbugs are often found grouped together in large clumps. The value of this clumping in conserving moisture can be demonstrated. Place a single sowbug or pillbug in one container. Place twenty-five or more animals in another. Leave both under identical conditions in dry air for a day. The single sowbug will soon die, while the others will survive.

Molting, or ecdysis, may be observed if the animals are kept over a period of time. A lightening of the animal's color precedes this process. Whitening occurs early at the anterior border of the fifth thoracic segment and extends posteriorly to other segments until this part of the exoskeleton is loosened and the animal steps out of the discarded exoskeleton. Two or three days later it sheds the anterior portion. Since only some of the legs molt at a given time, those not molting provide support during the process. After a molt the isopod is helpless for several days.

Student observations—answers to questions.

- (a) No.
- (b) On the wet blotter in one dish; they were scattered in the other.
- (c) On the wet blotter.
- (d) Under the covered half.
- (e) Move away from the warmer part of the dish.
- (f) Stay in the same place or are dispersed throughout the dish.

Interpretation. These animals cannot live without moisture because their gills require it for the respiratory process. They are negatively photoactive and will also avoid light. They search for food at night. They are also negatively thermotactic. The experiments suggest that sowbugs and pillbugs require a moist, cool habitat.

C Part 5 Effect of Temperature Changes on the Heartbeat of *Daphnia*

Suggestions for procedure. The influence of external factors on the processes of organisms and homeostatic adjustments to maintain a proper balance with the environment are of great interest to the biologist today. Such a physiological adjustment to varying environmental factors is illustrated in the rate of heartbeat of *Daphnia* in response to temperature fluctuations.

The investigator will need a good *Daphnia* culture since he will probably use many specimens. Water temperatures involved in the experiment must be accurate. The

Daphnia should remain one minute to adjust to each new temperature before the rate of heart beat is determined. The investigator might try several *Daphnia* at each water temperature to determine the extent to which the heart beats vary in different individuals.

Analysis and conclusions. Exact results of this Investigation cannot be anticipated. Other investigators have reported that *Daphnia* can easily tolerate variations in temperature from 5°C to 35°C. At 2°C the heart beat has been found to be about 180 beats per minute. As the water temperature increases, the heart beat also increases. At 30°C, the rate increases to about 270 beats per minute.

Chapter 31

Insects—A Representative Study

The grasshopper is presented as a representative insect in this chapter. It is a good subject for teaching external structure and adaptations of an insect, since its structures show plainly. Knowledge of the grasshopper can be applied to the study of other insects as a basis for comparison and illustration of the great number of structural and functional variations that have made insects so successful and prominent in the world.

In teaching the grasshopper, we suggest that you emphasize the characteristics it shares with all insects as a member of the class Insecta. Then, point out the characteristics that are peculiar to grasshoppers and their close relatives as characteristics of the order Orthoptera. In teaching the life activities and metamorphosis of the grasshopper, the many reasons why insects may become pests are apparent.

The students should bring in many specimens of Orthoptera so that they may be compared. Be certain that they know the differences between spiders and insects.

P. 423, right column: A collection of live or dead insects involves the learning of many techniques—collecting, observing, classifying, preserving, and understanding insect habits. Films, charts, pictures, and specimens are good for presenting life histories.

P. 424, Fig. 31-1: Which is better—plow late or early in the fall and why?

P. 425, Fig. 31-2: Analyze the meanings of terms like *metamorphosis*, *antenna*, and the names of insect orders. Latin students can be an asset.

P. 427, Fig. 31-4: Keep live grasshop-

pers in a container with grass or lettuce. Use this insect to emphasize the characteristics of insects, of members of the Orthoptera, of a successful organism which has become a pest, and as an example of incomplete metamorphosis.

P. 430, left column: Insects have been written about scientifically and fancifully by many. There are Aesop's Fables about the ant and grasshopper.

P. 430, Fig. 31-8: Crickets have been kept as pets for centuries by the Chinese. Some mail-order houses carry bamboo cages like the Chinese use. Fireflies have been used for the study of cold light. Have students look up the story of the monument to gulls in Salt Lake City.

MAJOR CONCEPTS

1. Three quarters of all classified animals are arthropods, and of these, the insects are the most numerous.
2. Although insects reproduce rapidly, the food requirements are so varied that they can maintain great numbers without interfering with one another.
3. A high degree of specialization occurs in the insects.
4. Most insects undergo several distinct stages during development from egg to adult. This is called metamorphosis.
5. Metamorphosis in insects is under hormonal control.
6. Although diversity among the insects is pronounced, the grasshopper can be used as a representative to illustrate the various systems.
7. Action of the wings and movement

of the abdomen pumps air in and out of the tracheae.

8. The circulatory system is similar to that of the crustaceans.

9. Sensory organs are well-developed.

10. The brain and ganglia of the ventral nerve cord coordinate movement and responses to stimuli.

11. Grasshoppers reproduce sexually and the sexes are separate.

Suggested Films

Joint-Legged Animals: Arthropods (b&w&col, 19 min) EBF

Metamorphosis (col, 28 min) AIBS McGraw-Hill

The Grasshopper: A Typical Insect (b&w&col, 5½ min) Cor

ANSWERS TO QUESTIONS FOR REVIEW (Page 431)

1. The grasshopper has an exoskeleton, segmented body, and jointed appendages—all characteristics of the phylum Arthropoda.
2. The grasshopper has a body consisting of three distinct regions, three pairs of legs, one pair of antennae, two pairs of wings, and breathing tubes, or tracheae.
3. The tympanum and ear cavities of the grasshopper are situated on the first segment of the abdomen. Other sense organs are on the head.
4. The first and second pairs of legs of the grasshopper are used in walking and clinging. The third pair is greatly developed for leaping.
5. a. *Skeletal*, for support and protection of the inner organs and tissues; b. *muscular*, for locomotion; c. *digestive*, for the intake and preparation of vegetable matter for body use; d. *circulatory*, for the movement of blood through vessels and into the body spaces for supply of the tissues; e. *respiratory*, for the exchange of gases between the tissues and blood and the trachea tubes; f. *excretory*, for the discharge of all cell wastes; g. *nervous*, for the receiving of impressions from the sense organs and control of body activity; h. *reproductive*, for the pro-

duction of eggs and sperm and fertilization of eggs.

6. The blood of man flows in a closed circulatory system; that is, it remains in vessels, except for the plasma which seeps into the tissue spaces. Blood in the insect's body leaves the vessels and enters the body cavities in an open circulatory system.
7. In man, air passes into the lungs, where the blood receives oxygen and discharges carbon dioxide. The blood contacts the tissues. In the insect, many branching trachea tubes carry air directly to the tissues.
8. The grasshopper has an incomplete metamorphosis. The eggs hatch into nymphs, which molt several times during the season. The last molt produces the adult stage.
9. The eggs of a grasshopper, laid in the fall, are deposited in a hole dug in the ground by the ovipositor of the female.
10. The praying mantis is a beneficial relative of the grasshopper. It destroys large numbers of harmful insects.

ANSWERS TO APPLYING PRINCIPLES AND CONCEPTS (Page 431)

1. First, breathing does not involve pressure changes in a body cavity, as in the human chest. Second, the insect does not maintain a constant body temperature and can remain alive at low temperatures until its protoplasm can no longer function. Third, the exoskeleton gives excellent external protection.
2. Insects outnumber all other groups of animals. They endure drought, food shortage, and other unfavorable conditions in which most other animals perish. They are highly adaptable and reproduce at a rapid rate.
3. The complete metamorphosis includes a resting stage known as the pupa. The insect can endure unfavorable conditions in this stage and emerge as an adult early in the next favorable season, without having to pass through a series of nymph stages.

Guide to Laboratory Investigations for Chapter 31

INVESTIGATION 31-1

The Grasshopper

Scope of the Investigation The grasshopper is frequently used to represent insects as a class because it is large, familiar to most students, and easily obtained for laboratory study. The examination of external and internal structures in this Investigation correlates with the discussion on pp. 426-430 of the text. Having become familiar with the anatomy of the grasshopper, the student is prepared to extend his study of insects to many additional areas of investigation.

Approximate time required The examination of external structures and suggested drawings should be completed in 45-50 minutes. The dissection and drawing of internal organs in Part 2 will require up to 90 minutes, depending on the time spent in preparing the drawing.

A Part 1 External Anatomy

Suggestions for procedure. Preserved grasshoppers are suggested for this Part. However, if living adult grasshoppers are available, the teacher may prefer to make use of them. Biological supply companies can furnish several kinds of large grasshoppers which are ideal for laboratory examination. Lubber grasshoppers (*Romalea*), collected in the southern states, have a body length of 2-3 inches. The flying grasshopper (*Schistocera*) is nearly as large.

The student should relate structure to function in the examination of a grasshopper. By examination of the mouthparts, diet and feeding habits may be determined. The form of the appendages indicate methods of locomotion. Capability of sensory responses is revealed in the degree of development of the sense organs.

Student observations—answers to questions.

(a) Soft plant tissues.

A Part 2 Internal Anatomy

Suggestions for procedure. Since the grasshopper is a small specimen for dissection, each student should be provided his own material, if possible. If students work in pairs at a laboratory table, it is often advisable for one student to dissect the abdomen from the dorsal side (as directed) while the other makes his incision on the ventral side. The dorsal incision may damage the heart but will not damage the ventral nerve cord. On the other hand, the ventral incision may damage the ventral nerve cord but will not damage the heart. The students may see both structures clearly. The drawing suggested should be accurate but need not be detailed. Color (one for each system shown) may be used for emphasis. A wall chart or a model of a dissected grasshopper will be a valuable teaching aid in directing the study of internal anatomy.

Chapter 32

Insect Diversity

This chapter covers a large part of the insect world. Ten common orders are introduced. In teaching these orders, we suggest that you point out the vast number of structural variations which characterize insects.

The butterfly provides a good comparison with the grasshopper. Differences in the mouthparts, use of the legs and wings, and the metamorphosis are striking. Bees, ants, and wasps introduce the many activities of a social colony. This is an opportunity to discuss instinctive behavior. The structural and functional differences between a queen, a drone, and a worker should be noted.

Students who are interested might observe an ant colony over a period of time. These colonies can be made or purchased from supply houses. Encourage the better students to do other projects related to insect study. These could include a collection of insects, a collection of life stages of one or more insect, a specialized collection showing protective coloration and resemblance, a collection of a single order, or a specialized collection of insects found in a garden. During the winter, a collection of cocoons and chrysalises can be assembled. The moths and butterflies usually emerge late in the winter or early in the spring and can be added to a collection in perfect condition if desired.

Abundant material for special reports on insect pests and control measures can be found in various bulletins of the United States Department of Agriculture as well as in state publications. Other projects might include a visit to a greenhouse to get information on insect pests and control measures being used, or a survey of insecticides available in a seed store and their specific uses and directions for use.

P. 433, right column: Temporary or permanent slides of insect parts like fly legs, wings, proboscis, and moth and butterfly scales can be made by interested students. A collection of these slides can also be obtained from a supply house and kept on hand for future study. These activities will provide invaluable experience for those students who are seriously considering entering a specialized branch of science, or who intend to obtain a regular position as a laboratory assistant.

P. 434, right column: Find insects in winter: a. that live in cocoons or chrysalises (cecropia, bagworm); b. that live in ponds and streams as egg or larvae (dragonfly); c. that live on land as eggs (mantis, tent caterpillar); d. that live in houses and barns (fly, mosquito, roach).

P. 435, Fig. 32-4: Review symbiosis of the termite and protozoan on P. 439.

P. 437, right column: There are many kinds of honey produced, depending on the plants the bees have frequented.

P. 438, right column: Reports can be made on social insects like the ant and bee and other insects with odd habits like the parasol and army ants. Formic acid irritates the skin when ants bit.

P. 439, left column: The ichneumon fly is used as a biological control for destructive insects. Ladybird beetles are also used for controls, and are sold by the bucketful. They are inactivated for shipment by refrigeration.

P. 441, Fig. 32-9: Slides of the fly proboscis are easily made by mounting the material in Canada balsam.

P. 442, Fig. 32-10: If oil is sprayed on the surface of the water, it prevents the wigglers from getting air. This is a common method of mosquito control.

P. 444, table: Show as many examples of these as possible by using films, charts, pictures, or mounted specimens.

Suggested Films

Insects and Spiders (col, 28 min) AIBS McGraw-Hill

Social Insects: The Honeybee (b&w&col, 24 min) EBF

Termite Colony: A Complex Social Organization (b&w&col, 11 min) Cor

The Butterfly (Life Cycle of an Insect) (b&w&col, 5½ min) Cor

MAJOR CONCEPTS

1. The success of the insects can be attributed, in part, to a behavior much more complicated than the lower invertebrates. Development of more complex sense organs, jointed appendages, and a brain have allowed a more complicated behavior.
2. The receptors of an insect allow it to receive stimuli from the immediate environment and also from some distance away.
3. Some insects are able to modify their environment by building homes and nests.
4. Some insects live in symbiosis with other organisms.
5. Some insects form societies and thus divide the labor of the group.

6. Similarities can be observed among great insect diversity and these are the characteristics of the various orders.
7. Communication among insects may be detailed and complex as in the bees.
8. Some insects use the sun as a navigation guide.
9. A knowledge of insect life histories is essential when man considers their control a necessity.
10. Man has utilized chemicals, natural enemies, sterilization procedures, and environmental changes in controlling the numbers of insects.

ANSWERS TO QUESTIONS FOR REVIEW (Pages 448-449)

1. Insects have adapted to terrestrial life in numerous ways. They have a more complicated behavior than lower invertebrates because of complex sense organs, jointed appendages, and a brain. They can perform complicated, coordinated acts and can modify their environment by building many kinds of homes and nests. Many live in societies and have division of labor.
2. The coiled proboscis of a butterfly is formed from the greatly modified maxillae. The maxillae are also grasshopper mouthparts.
3. Many Lepidoptera are extremely destructive in the larva stage as, for example, the clothes moth, codling moth, European corn borer, and cabbage butterfly.
4. Many people assume that Hymenoptera learn to perform their specialized tasks. However, these result from purely automatic behavior and not from learning.
5. A hive contains a queen, many workers, and drones (at certain times). The queen lays eggs and is the hive mother. Workers perform all tasks relative to maintaining the hive and rearing the young bees. Drones have no function except mating with the new queen.
6. Recent discoveries reveal that bees perform a peculiar dance which communicates the location of a nectar supply.
7. Both the larvae and adults of Neuroptera have chewing mouthparts and eat aphids.
8. Eggs of the housefly are laid in garbage, sewage, and other organic matter on which the fly larvae can feed. The larvae, or maggots, feed for about five days, then enter the pupa stage from which the adult emerges after about a week.
9. If the breeding areas of flies and mosquitoes are destroyed early in the season, the numbers can be so reduced that extensive campaigns later may be avoided.

ANSWERS TO APPLYING PRINCIPLES AND CONCEPTS (Page 449)

1. Insects are able to modify their environment by building many kinds of homes and nests.
2. The students may be able to think of many experiments, some of which may involve colors, scents, or varying light concentration.
3. Blind fish live successfully in underground streams in caves. Moles are nearly blind, yet are not hindered in any of their life activities.
4. A little fly does not grow up to become a larger fly. Regardless of size, a fly is an adult stage and is beyond the period of growth, which occurred as a larva.
5. It is best to kill the adult fly. Just before breeding, the fly must feed for about fourteen days. Spraying the food will kill the hungry fly.

Suggested References for the Teacher—Unit V

Books

Cousteau J. G. and Dumas, F. *The Silent World*. Harper and Row, New York, 1953
Daniel, Hawthorne and Minot, Francis.

The Inexhaustible Sea. Dodd, Mead and Co., New York, 1958

Dethier, V. *To Know a Fly*. Holden-Day, San Francisco, Calif., 1962

- Easton, W. H. *Invertebrate Paleontology*. Harper and Row, New York, 1960
- Frisch, K. Von. *Bees: Their Vision, Chemical Senses, and Language*. Cornell University Press, Ithaca, 1956
- Halstead, Bruce. *Dangerous Marine Animals*. Cornell Maritime Press, Cambridge, Md., 1958
- Hausman, L. S. *Beginner's Guide to Fresh-Water Life*. G. P. Putnam's Sons, New York, 1959
- Klots, A. B. and Klots, E. B. *Living Insects of the World*. Doubleday & Co., New York, 1959
- Klots, Alexander. *The World of Butterflies and Moths*. McGraw-Hill Book Co., New York, 1958
- Lapage, G. *Animals Parasitic in Man*. Penguin Books, Baltimore, Md., 1957
- Little, V. A. *General and Applied Entomology*. Harper and Row, New York 1957
- Moore, R. C., Lalicker, C. G., and Fischer, A. G. *Invertebrate Fossils*. McGraw-Hill Book Co., New York, 1952
- Pennak, R. W. *Fresh-Water Invertebrates of the United States*. The Ronald Press Co., New York, 1953
- Prosser, C. L. and Brown, F. A., Jr. *Comparative Animal Physiology*, 2nd ed. W. B. Saunders Co., Philadelphia, 1961
- U. S. Dept. of Agriculture. *Insects*. Supt. of Documents, Govt. Printing Office, Washington, D.C., 1952
- Verrill, A. H. *Strange Creatures of the Sea*. Grosset and Dunlap. New York, 1955
- Articles*
- Allen, Robert D., "The Moment of Fertilization." *Scientific American*, July, 1959
- Alvarado, Carlos A., And Bruce-Chwatt, "Malaria." *Scientific American*, May, 1962
- Beroza, Morton, and Martin Jacobson, "Insect Attractants." *Scientific American*, August, 1964
- Berrill, N.J., "The Indestructible Hydra." *Scientific American*, December, 1957
- Cadart, Jean, "The Edible Snail." *Scientific American*, August, 1957
- Editors of LIFE, TIME, INC., *The Sea*, Time, New York, N.Y., 1964
- Edwards, John S., "Insect Assassins." *Scientific American*, June, 1960
- Hawkins, F., "Filariasis." *Scientific American*, July, 1958
- Hayashi, Teru, "How Cells Move." *Scientific American*, September, 1961
- Hocking, Brian, "Insect Flight." *Scientific American*, December, 1958
- Holmberg, Lars, "An 'Antlered' Grotesque." *Natural History*, February, 1964
- Klotz, Alexander B., "The Monarch's Emergence." *Natural History*, May, 1964
- Lane, Charles E., "The Portuguese Man-of-War." *Scientific American*, March, 1960
- Lane, Charles E., "The Tereido." *Scientific American*, February, 1961
- Luescher, Martin, "Air-conditioned Termite Nests." *Scientific American*, July, 1961

UNIT SIX

BIOLOGY OF THE VERTEBRATES

This unit is a climax in the study of animal biology and a background for the study of human biology in the next unit. The opening chapter introduces the vertebrate plan of structure and outlines ten systems of the vertebrate body. In addition, it points out the functional efficiency that has given the vertebrates supremacy among living things. The introduction of the seven classes of vertebrates, with examples listed for each class, gives the student a preview of the chapters to follow, in which each class will be presented in detail. The vertebrate classes are studied in order of increasing complexity. Each organism is presented as a complete structural and functional unit in which organs, systems, and functions are interrelated. As the student progresses through the study of vertebrate classes, he becomes aware of the increasing complexity of the body organs and increasing functional efficiency. This logically leads to the mammals.

Many aspects of vertebrate study are important. Knowledge of structure is essential to the study of function and behavior. The natural history and ecological phases of vertebrate study are of special interest because of the economic importance of vertebrates and familiarity of the average student with large numbers of these animals. Although treated in a later unit, ecology and conservation should not be omitted from discussions in this unit.

OUTCOMES

The study of this unit should result in:

1. Understanding of the place of vertebrates in the living world.
2. Familiarity with the characteristics that set vertebrates apart from other animals.
3. Understanding of the reasons for vertebrate supremacy.
4. Acquaintance with the classes of vertebrates.
5. Knowledge of the structure of the organs and systems of vertebrates and their functions.
6. Understanding of the increase in complexity of the organs of vertebrates, from the lower forms such as Cyclostomata to the mammals.
7. Broadened acquaintance with vertebrates of your region.
8. Interest in conservation problems relating to vertebrates.
9. Awareness of the tremendous economic importance of vertebrates.
10. Understanding of man's relationship to the other vertebrates.
11. Acquiring of background knowledge valuable in the study of the human body.
12. Introduction of hobbies and leisure-time activities involving vertebrates in some manner, such as collection and field study.

Chapter 33

Introduction to the Vertebrates

The opening section of this chapter reviews certain of the invertebrates previously studied and points out various lines of development. The vertebrate form of structure is then contrasted with that of invertebrates as a means of pointing out reasons for vertebrate supremacy in the animal kingdom. These are important topics for class discussion. We refer briefly to the characteristics of the Chordata as a means of classifying the vertebrates, and give brief reference to the other subphyla of chordates. This classification can be shown graphically in a chordate tree, prepared on a large sheet of paper or cardboard. The trunk of the tree is labeled *Chordata*. Four main branches represent the subphyla and should bear their names (see the Appendix of MODERN BIOLOGY, p. 751). One branch, the vertebrates, has seven smaller branches growing from it. These are the seven classes of vertebrates and should be so named. At the end of each branch of the

tree, show a small drawing of a representative animal in the subphylum or class.

Photographs and pictures from magazines displayed on bulletin boards can be utilized to familiarize the students with the characteristics of the different classes. Living and museum specimens can be displayed and observed as the various characteristics are discussed.

P. 453, Fig. 33-1: *Amphioxus* can be obtained from a supply house and the preserved specimen used for years.

P. 453, left column: For the evolutionary development of fish, consult the chart on page 183.

P. 453, right column: Review p. 186, Fig. 13-4 on the development of vertebrates.

P. 455, right column: In discussing behavior, review tropisms and develop the idea of the value of reflexes to man. Use specific examples of reflexes like blinking.

P. 456, Fig. 33-2: Point out that these

animals are not drawn to scale. For each tell briefly some fact of natural history: The leopard is a cat with retractible claws; the only cat that cannot retract its claws is the cheetah. The broken color pattern makes it more difficult to see the animal where sunshine is filtered through leaves. The common herring gull has a bright orange spot on its bill which attracts the young when they try to pull down the adult's bill filled with food. Salamanders are often mistaken for lizards but they have no scales. The box turtle has an unusual courting habit. He rears on his hind legs and comes down on the female's shell with a bang! Other facts can be obtained from your reading.

P. 457, Fig. 33-3: The opossum is the only North American marsupial and has a gestation period of 13 days, the shortest of the mammals.

P. 457, left column: A good example of instinct is the building of a web by a spider. If the animal is disturbed in the complicated process of spinning an orb web, it must begin again from the beginning. Nest building by birds is also an example of instinctive behavior.

P. 457, right column: Although man has spoken and written communication, other animals communicate with sounds. This is a topic for a student report or it can be used by the teacher when talking about animal habits. An animal learns by repetition.

MAJOR CONCEPTS

1. The highly developed vertebrate brain and nervous system make up for the lack of outer protection.
2. Early in life all chordate animals have a notochord. Some keep the notochord throughout life, but most replace it with cartilage or bone forming the vertebral column.
3. The vertebrates have a dorsal nerve cord and a ventral circulatory system.
4. From fossil records, scientists have drawn conclusions as to the order in which vertebrate animals arose and inhabited the earth.
5. The vertebrate systems contain many highly developed organs.
6. The classes of vertebrates show an

interesting change from water existence to life on land.

7. The increase in complexity and efficiency of the vertebrate heart and brain are used to construct evolutionary theories.
8. The highly developed sense organs, brain, and nerves extending to and from all parts of the body provide the basis for complex behavior.
9. Self-preservation and species preservation are instincts.
10. Vertebrates are capable of learned behavior, but intelligent behavior is still more complicated.

ANSWERS TO QUESTIONS FOR REVIEW (Page 458)

1. The vertebrate skeleton is internal and is called an endoskeleton.
2. a. Cyclostomata (lamprey); b. Chondrichthyes (shark); c. Osteichthyes (bony fish); d. Amphibia (frog); e. Reptilia (snake); f. Aves (bird); g. Mammalia (leopard).
3. The endoskeleton is the more efficient because it allows greater development of other organs and greater freedom of motion.
4. The notochord is a gristlelike rod running lengthwise along the dorsal side of a chordate.
5. Chordates have a notochord at some time in life, a dorsal nerve cord, and paired gill slits in the throat which may or may not disappear. Vertebrates have these characteristics and, in addition, have a spinal column (for which the subphylum is named) two body cavities, and an internal skeleton.
6. a. A body with a head and trunk and, in some, a tail; b. never more than two pairs of locomotive appendages (limbs); c. eyes, ears, nostrils in the head; d. eyelids, and separate teeth usually present; e. an internal skeleton of bone or cartilage; f. a spinal column composed of vertebrae; g. a dorsal and ventral body cavity; h. a heart on the ventral side of the body, blood containing red corpuscles.
7. a. Integumentary; b. muscular; c. skeletal; d. digestive; e. respiratory; f. circulatory; g. excretory; h. endocrine; i. nervous; j. reproductive.

8. The cerebrum of the brain is the center of instinct, emotions, and intelligence.
9. The stimulus is the external condition which causes the nervous reaction, or response.

ANSWERS TO APPLYING PRINCIPLES AND CONCEPTS (Page 458)

1. Members of the classes Cyclostomata and Chondrichthyes have a cartilaginous skeleton throughout life. Vertebrates above these classes have a bony skeleton. Through the classes of vertebrates, there is a gradual transformation from gill breathing to lung breathing. Those below the amphibians are gill breathers as adults. Those above amphibians are lung breathers as adults. The class Amphibia is the transition stage with some of the adults gill breathers and others lung breathers. The hearts of vertebrates show a gradual develop-

ment from a two-chambered structure, through a three-chambered stage in amphibians, to a four-chambered heart in the bird and mammal. Brain development shows a gradual increase in the relative size of the cerebrum in the various classes.

2. Species preservation is a stronger instinct than self-preservation when it is present. An animal will sacrifice its life in defense of its young.
3. Instincts are universal in a particular kind of vertebrate. Therefore, all members of a species respond to the instinct in the same way. Intelligent behavior varies with the individual animal and the conditions confronting it.
4. Instinct and intelligence are more vital to a vertebrate than to an invertebrate because, lacking the external protection of a clam, a starfish, or a crayfish, the vertebrate must face its survival problem and flee or fight.

Chapter 34

The Fishes

Three vertebrate classes are included in this chapter. The sea lamprey represents the class Cyclostomata. This lower vertebrate has become extremely important in recent years because it had destroyed enormous numbers of fish, especially lake trout, in the Great Lakes. Sharks and rays are mentioned briefly as representatives of the class Chondrichthyes. Museum specimens of lampreys, small sharks, and rays are available at biological supply houses. The structure of these lower vertebrates is so different from that of the bony fish that students might use them to good advantage for comparison.

The bony fish, to which most of the chapter is devoted, is the first vertebrate studied in detail. A living fish in a small aquarium (goldfish and catfish are good) is a good introductory study. The rising and sinking of the fish in the water shows the equalization of the fish's weight and the weight of displaced water, provided by the swim bladder. Emphasize also the pumping

action of the operculum in drawing water over the gills.

A community aquarium, maintained in the laboratory and stocked with small native fishes, is a good class project. A collection of goldfish of different types is a good introduction to a worthwhile hobby. The tropical aquarium described will require more special equipment but is very desirable because of the great interest in this hobby today. The students might be interested in examining books on tropical fish and magazines for aquarists.

Fish conservation measures and laws are presented in Chapter 53, pp. 723-741 of MODERN BIOLOGY, if you wish to include this phase of fish study here.

P. 461, Fig. 34-3: Mouth location is important in getting prey. *Gambusia* has the mouth on the upper surface of the head and so can go along scooping up mosquito wigglers which hang at the water's surface for air. Have pupils consult a dictionary to find the use of the word *fish* (fish denotes

one or a school of one kind of fish, *fishes* means different kinds).

P. 462, left column: Fishes and leeches are examples of organisms sensitive to vibrations in the water. Sound travels better through water than air. You can talk briefly here about the physics of sound.

P. 468, left column: Fish are obtained from drag nets at the surface or from the stomachs of species that come from greater depths. Because of the change in pressure, many of them burst.

P. 469, right column: Fish eggs sold for food are called roe. Caviar is fish eggs. Milt is also eaten. Students may be familiar with laws governing fishing, with equipment, and with local places for fishing. The information can be treated from the conservation angle (see pp. 732-734). Hatcheries make a very good topic for a student report.

P. 470, left column: In cooperation with the art department, students may wish to make a collection of fish prints as a means of showing various species or for framing as a decoration. Paper towels may be used and good quality rice paper for finished work. A local art supply store may be able to furnish rice paper or something similar, but if it is unavailable, handmade papers for this work may be obtained from Andrews-Nelson-Whitehead Inc., 7 Laight Street, New York, N.Y., 10013. Gyotaku (fish prints) are used in Japan for decorating paper fans and as signs indicating where fish may be bought. Use the following method:

- a. Wash the fish with water and salt or soap or detergent to get rid of the mucus. Sponge dry with a damp sponge to get rid of the water under the gills and the eye-socket.
- b. With absorbent cotton, stuff the gills to keep the water from leaking out.
- c. Prop the fish with plasticine clay so it is flat.
- d. Fins may be fanned out and pinned onto clay.
- e. Paint the fins with glycerine, using a small brush.
- f. Apply black or colored ink (Grumbacker in a tube is good) in loose consistency. Paint around the eye and always go with scales.
- g. Tack paper down near the tail. Slowly

and lightly press the paper on the fish. Remove carefully, then hang to dry.

The indirect method is to wet the paper and place it on the fish. A tamper is then used to dab the paint onto the paper. A tamper is made by stuffing cotton cloth into a piece of cotton and tying it around with a piece of string so that it looks like a mushroom.

Suggested Films

Fishes, Amphibians and Reptiles (col, 28 min) AIBS McGraw-Hill

Perch Anatomy (b&w&col, 17 min) Ind

What is a Fish? (b&w&col, 22 min) EBF

MAJOR CONCEPTS

1. Ancestors of the cyclostomes are believed to have been the first vertebrates.
2. The skeleton of the sharks, skates, and rays is composed of cartilage.
3. The bony skeleton distinguishes the true fishes from lampreys, sharks, and rays.
4. Gills are the respiratory organs in fishes.
5. The body covering and streamlined shape of a fish adapt it to a water environment.
6. As scales grow, concentric rings are formed.
7. Many fishes illustrate countershading.
8. The fish heart and brain is less complex than those of the amphibian.
9. The relatively large optic lobes of the brain of the fish indicate the importance of sight.
10. Scientists now believe that odors direct fishes to feeding areas among water plants.
11. The sexes of fish are separate and fertilization is external in most.

ANSWERS TO QUESTIONS FOR REVIEW (Page 471)

1. When the adult sea lamprey attacks a fish, it attaches its sucking mouth to the sides of the fish and chisels a hole through the scales with its rasping teeth.
2. As sea lampreys ascend the rivers and streams emptying into the Great Lakes to spawn, they are driven into traps by electrical charges and

are destroyed. A more recent method of sea lamprey control makes use of a poison which kills the larvae buried in the streams.

3. The shark differs from a bony fish in having a cartilaginous skeleton.
4. The slime on a fish's body serves as a lubricant in the water, protects it from parasitic fungi and parasites, and aids in escape from animals that are trying to seize it.
5. The dorsal side of the body contains dark pigments (chromatophores) which tone down the bright light striking the fish from above. Thus the dorsal side blends with the lighter side, giving the fish a uniform appearance when viewed from the bottom or with deep water when the fish is seen from above. The light colors on the ventral side blend with the bright light on the surface when the fish is viewed from below.
6. The fins of the yellow perch include: the dorsal or dorsals, along the top midline; the caudal, or tail fin; the anal fin, along the ventral midline and posterior to the anal opening; the pelvic fins, along the ventral side and homologous with legs; the pectoral fins, anterior to the pelvic fins. The dorsal fins serve for balance, for keels, and for protection; the caudal serves as the chief propelling fin; the anal serves as a keel and aids in maintaining balance; the pelvic and pectoral fins serve for balance, steering, and act as oars when the fish is swimming slowly.
7. Food enters the mouth, passes into the throat cavity, or pharynx, then into a short esophagus and into the stomach, and on to the intestine. Undigested particles leave through the anal opening.
8. The fish heart consists of an auricle and ventricle, with a sinus venosus above the auricle and a conus arteriosus at the base of the ventral aorta and joining the ventricle.
9. Deoxygenated blood flows through the ventral aorta to the afferent branchial arteries. These arteries

carry the deoxygenated blood through the gill arches to the gill filaments. Thin-walled capillaries in the gill filaments allow diffusion to take place. The blood gives up carbon dioxide and takes in oxygen molecules. The oxygenated blood is carried from the gill filaments by the efferent branchial arteries to the dorsal aorta.

10. The air bladder is a thin, gas-filled sac lying in the dorsal region of the body cavity. It adjusts the weight and displacement of the fish at various levels in the water.
11. The regions and functions of the fish brain, named from anterior to posterior end are, olfactory lobes (sense of smell), cerebrum (control of voluntary muscles and center of instincts), optic lobes (sense of sight), cerebellum (muscle coordination), medulla oblongata (nervous control of the internal organs).
12. Fish have a well-developed sense of sight. However, they tend to be nearsighted and probably do not see objects clearly at distances greater than a few feet. The range of vibrations to which the ears of the fish are sensitive is greater than that in humans. The sense of smell in the fish is very acute. Fish can distinguish the odors of many plants, even if dipped only for a short time in pure water. They can also detect the odor of hands washed in a stream as well as the odors of many animals, especially mammals.

ANSWERS TO APPLYING PRINCIPLES AND CONCEPTS (Page 471)

1. Scales are an ideal body covering for fish. They are smooth, and offer little resistance in the water; hard, to give protection, and overlapping, to give freedom of motion. Fins are excellent oars and keels for swimming and steering. The eyes permit a large field of vision. The lateral line is an excellent pressure organ. The bones of the skull carry vibrations to the auditory nerves, embedded in the skull.

2. Gill filaments dry out suddenly when exposed to the air. They are adapted to absorption of oxygen from the water, but cannot absorb it from the atmosphere.
3. Many fish eggs are not fertilized during the somewhat inefficient spawning process of most fish. Many eggs are eaten before they hatch. Young fish are the food supply of countless other aquatic animals. These, and climatic conditions, prevent fish from overpopulating waters in which there is a normal natural balance.

Guide to Laboratory Investigations for Chapter 34

INVESTIGATION 34-1

Study of a Bony Fish

Scope of the Investigation This Investigation is designed to introduce the student to the basic external structure of a vertebrate as compared with the invertebrates he has studied in Unit 5. It focuses the student's attention on the living bony fish, its appearance, and behavior (pp. 463-465, p. 469 of the text). The student observes a living fish and a preserved specimen in this study in an attempt to determine how the various body structures adapt the fish for a successful life in a water environment. Through the C-level Part 3, the student can observe protective color changes in living fish.

Approximate time required

Part 1—Approximately 30 minutes.

Part 2—A 40-50 minute period.

Part 3—Long-range project requiring 3-4 weeks or more.

A Part 1 Study of a Living Fish

Suggestions for procedure. Small living fish are required for Part 1. Goldfish are suggested because of their ability to survive in a small aquarium. However, any small native fish may be used. Even minnows obtained from bait shops are suitable if they are large enough for the students to observe easily. If the fish are to be retained for any length of time before or after this study, they should be placed in a large aquarium which contains a number of green plants and/or an aerator as a source of oxygen. The aquaria used for the student observation should be small enough to retain the fish where the students can see them, yet large enough for the fish to move in a natural manner. Students should be discouraged from tapping on the glass, dipping into the water, or otherwise disturbing the fish, since the goal in this Part is to observe the fish behaving as naturally as possible under laboratory conditions.

Student observations—answers to questions.

- (a) Elongated, smooth, spindle-shaped.
- (b) It is streamlined to offer the least resistance in moving through the water.
- (c) Closed.
- (d) Open.
- (e) They force water over the gills, where oxygen is removed from the water.
- (f) No.
- (g) Slightly movable.
- (h) Answers will vary; the pupil occupies approximately 50-70% of the exposed portion of the eye.
- (i) Light is rather limited under water; large pupils admit a greater percentage of this light.
- (j) The entire tail region.

- (k) Alternate contraction of the muscles along either side of the posterior part of the body provides forward thrust.

A Part 2 External Structure of the Yellow Perch

Suggestions for procedure. This Part is designed with the yellow perch in mind, but other carnivorous species may be substituted. If fresh fish are available, it is best to use them for this Part, for their color will be more natural at this time. If the fish are preserved at the end of this Part, they may be retained for the dissection in Investigation 34-2. Students should examine the fish thoroughly, handling them carefully to avoid the sharp spiny dorsal fin. For the study of the scales, forceps should be used to remove a few scales. A scale should be observed with a stereoscopic microscope if possible, or with a hand lens and then low power of an ordinary student microscope. The student should note the toothed margins and concentric rings in the scales. Some teachers prefer to include Part 1 of Investigation 34-2 at this point. If the fish are to be retained for later, they should be preserved in the following manner: prepare an 8% formalin solution and inject this deep into the alimentary canal through the mouth, using a large glass or plastic syringe. Allow some of the solution to flow freely over and between the gills. Make an incision in the ventral side of the fish, anterior to the anal opening, and inject some of the solution into the body cavity, allowing it to bathe the internal organs. Then put the fish in a container, completely cover them with the formalin solution, and keep the container closed.

Student observations—answers to questions.

- (a) Yes.
- (b) Yes.
- (c) They are very tiny, quite sharp, and slant backward.
- (d) Catching the holding prey.
- (e) The shape and position of the teeth indicate that they enable the yellow perch to catch other fish and hold them in the mouth, making it hard for the prey to escape.
- (f) It is short and attached to the floor of the mouth.
- (g) A sense organ for touch.
- (h) They are two sets paired openings, one on either side of the midline, on the top of the head.
- (i) No.
- (j) No.
- (k) Sense of smell.
- (l) Four.
- (m) The fish often swallows very large prey.
- (n) To a limited extent.
- (o) Seals the operculum against the gills to close the gill chamber.
- (p) Increases circulation of water over the gills; allows greater movement of the water in the chamber.
- (q) Separated.
- (r) Approximately 12.
- (s) Variable to a limited extent; generally 10 to 15.
- (t) Soft, branching structures.
- (u) Pectoral—generally 1 spine, the others rays.
Pelvic—generally 1 spine, the others rays; anal—spines and rays; caudal—all rays.
- (v) A row of pitted scales along the side of the body.
- (w) There are pits and canals through the scales.
- (x) They overlap toward the back in a manner similar to shingles on a roof.
- (y) Rather oblique.
- (z) Answers will vary.

C Part 3 Effect of Environment on Color Changes in Fish

Suggestions for procedure. The fish used in this experiment should be from 3 to 5 inches long. Six of them (if this number is available) should be lacking scales and be a rather solid color, such as bullhead catfish. The other six should have scales and be patterned with spots or bars, such as green sunfish. An aquarium for each fish is necessary, as is white, brown, black, yellow, green, and red paper. This paper should be used to cover the bottom and sides of the aquaria completely, using a different color for each of the six fish of one type and the same assorted colors for the other six fish. Water in the aquaria should barely cover the top of the dorsal fin of each fish, so that the fish will aerate the water with their own activity. Note that the top light over all the aquaria should be equal, and the water should be changed in such a manner that the fish are not exposed to daylight. The fish should be observed daily for any evidence of color change. Larger fish will require more time to show any changes. At the end of the study, some of the fish may be used for microscopic studies of the skin.

Analysis and conclusions. Results will vary with the type of fish used, the size of the fish, the color of the paper, and the length of the study. If bullhead catfish and green sunfish are used, students may expect results similar to the following. In the black aquaria, the bullhead catfish tends to turn jet black, and the bars on the green sunfish darken considerably. In the brown aquaria, results are similar to the black, though not as dark. Both the catfish and the sunfish tend to become lighter in color in the yellow aquaria. The green tends to increase the iridescence of the sunfish, while the catfish do not change at all, or lighten only slightly. In the white aquaria both fish tend to bleach out considerably. The red color seems to have little effect on either the catfish or the green sunfish.

INVESTIGATION 34-2

Dissection of the Fish

Scope of the Investigation Through this Investigation the student should gain an awareness of the internal structure of a fish, which enables it to live successfully in the water (pp. 465-470 of the text). Also, the fish illustrates certain vertebrate characteristics which the student will observe slightly modified in other vertebrates he will study. Thus the fish gives the student a basis for his study of the various lines of vertebrate development as outlined on pp. 454-455 of the text.

Approximate time required Part 1 should be completed within 20-30 minutes. Some teachers may prefer to combine Part 1 with Part 2 of Investigation 34-1. Part 2 should require a period of 50-60 minutes.

A Part 1 Structure of the Gills

Suggestions for procedure. A preserved fish such as yellow perch is required for Parts 1 and 2. However, some teachers prefer to combine this Part 1 with Part 2 of Investigation 34-1, if fresh fish are available for that study. In the fresh fish the gills have a better color and texture. Also, the gills tend to deteriorate if not preserved carefully. The left side of the fish should be dissected. After observing the gill and operculum positions, the operculum should be removed with scissors and one of the gills removed by clipping either end of the arch. Students should be encouraged to work carefully to remove as much of the C-shaped arch as possible. The gill should be rinsed to remove the mucous coating and examined carefully, noting especially the location of the afferent and efferent branchial arteries.

A Part 2 Internal Structure of the Fish

Suggestions for procedure. The initial incision should be made ventrally from the anal opening to the isthmus. Students should be cautioned against cutting too deeply and damaging the intestine or heart. The left side of the body wall should be removed according to directions in the student manual, taking care to avoid breaking the air bladder if possible. The student should locate all of the organs listed in italic type in the student manual. The alimentary canal should be removed by clipping the intestine at the anal opening and the esophagus as near the mouth as possible. After removing the alimentary canal and drawing the organs, students may wish to open the stomach to reveal any identifiable contents. Class members may wish to tabulate their results to see if they can determine on what the fish were feeding at the time they were caught. Small fish and crayfish are often found in yellow perch. The student should continue his study with the urogenital system. Occasionally the egg-filled ovary of the female will be so large that it interferes with study of the other organs and will have to be removed early in the dissection. The kidneys appear as dark blotches along the spine. By sectioning the isthmus carefully, the student should be able to expose the heart and identify its parts. The brain dissection can be rather tedious, but quite satisfying. Students should be strongly urged to work slowly and carefully, *scraping* the bone away gradually rather than attempting to chip it away. When the bone is worn quite thin, forceps should be used to lift the pieces of skull away from the brain, taking care not to dig into the brain itself. Some students may be able to pursue this study and dissect out the brain, spinal cord, and some of the spinal nerves.

INVESTIGATION 34-3

Effect of Temperature on Goldfish Respiration Rate

Scope of the Investigation In this Investigation the student is actually observing an example of homeostasis, which he studied on pp. 70-71 of the text. The increase or decrease in operculum movements is a self-regulating mechanism in response to the variations in the water temperature. The inactivity of the goldfish and lack of operculum movements at low temperatures and the active swimming and rapid movement of the operculum at high temperatures demonstrate that there is a direct relationship between body temperature, metabolic activity, and respiration rate.

Approximate time required 50-60 minutes are required to complete this Investigation. Time may be saved if the goldfish is put into the aquarium before class. The class should be divided into teams for this activity.

B Part 1 Effect of Water Temperature on the Respiration Rate of the Goldfish

Suggestions for procedure. The goldfish may be purchased from fish hatcheries and should be comets, if possible. These are hardier than the fancy breeds and can withstand the extremes in temperature changes to which the fish are subjected.

Any movement in the water that disturbs the fish may alter the respiration rate. Thus a thermometer with a dial face is best to use, since it can be read without disturbing the fish. After the ice is added, some of the fish may become numb and lose their sense of balance, turning on their sides, but they will probably recover. The operculum probably will not move at temperatures near freezing.

After the data is recorded in the table, a line graph should be constructed showing the averages. There should be a gradual increase of operculum movements from 0 at the near freezing temperature to 120-125 at the highest temperature.

Student observations—answers to questions.

- (a) Would increase activity, thus increasing respiration.
- (b) Should include the slowing down of movement of fins during low temperature, the increase of activity as water temperature increases, and finally the gulping of air at high temperatures.
- (c) Should be 92°F.

Interpretation. There is a direct relationship between increase in water temperature and respiration rate in the goldfish.

In addition to water temperature, the age of the fish, minerals in the water, health of the fish, and general disturbance of the water due to the presence of the thermometer influence the metabolic rates.

Increase of temperature or decrease destroys the enzymes necessary for energy release. Internal tissues suffer from lack of energy and from an accumulation of intermediate substances that the cells cannot metabolize, and they finally die.

Because the respiration rate varies according to water temperature, the metabolic rate may be the same in fish in the two environments.

Chapter 35

The Amphibians

The study of Amphibia, and especially the frog, is a high point in most biology courses. These vertebrates demonstrate clearly the transition from aquatic to terrestrial forms. The anatomy of the frog, stressed in this chapter, is an excellent introduction to the study of the structure of higher animals and man to follow. The "Trans-Vision" of the frog between pp. 488 and 489 of MODERN BIOLOGY will be useful in teaching both external and internal structures.

The significance of the dependence on water as environment during one phase of the frog's life history should be discussed. The transition of the gill-breathing tadpole to the lung-breathing adult is interesting and the importance of the change should not be overlooked. The mechanisms involved in the absorption of materials from the tail are not well understood and, therefore, can be presented as an area of current research. What factors might be involved to cause the cells of the tail to disappear?

Amphibians have chromatophores and guanin crystals which may, in some, allow them to change color to blend in with the surroundings. Discussions on the survival factor and the control of these changes allow an opportunity for interesting library work.

P. 475, left column: When there is confusion as to the identity of a species, it may be due to poor observation or because the taxonomic differences are so small.

P. 475, right column: The spotted newt has several interesting habits. It has a courtship dance, it migrates in large swarms from the spot of winter hibernation to the ponds, and appears in the woods after rain.

P. 476, left column: Some toads and frogs have unusual habits. The Surinam toad carries the young in separate pouches on the back and when the tadpole stage is passed, the toad goes to the water to allow the young to escape. Spadefoot toads burrow into the ground backwards. Male obstetrical toads carry egg strings wound around their hind legs. They carry the developed tadpoles to the water to allow them to escape.

P. 476, right column: Although spring peepers are no bigger than the end of the thumb, their song can be heard about one mile away because of the resonating chamber.

P. 478, left column: A frog's front legs aid in pushing food into his mouth.

P. 479, Fig 35-5: Use the diagram as a laboratory guide. In this, and in all other diagrams, have students avoid the temptation to copy.

P. 482, left column: The frog brain and spinal cord can be dissected and Fig. 35-8 used as a label guide for the dorsal view. Some students do well and are able to remove the optic nerves and nerve branches at the end of the cord as well as the pituitary body on the ventral side.

P. 483, left column: Mating in frogs is called amplexus. Turn over a mass of eggs, which has the dark side uppermost, so that the lighter side is then uppermost. Observe after 24 hours.

P. 484, Fig. 35-10: Discuss the life history of the frog and stress the dependence of amphibians on water.

P. 485, right column: Students can find the fat bodies in their laboratory specimens. When are they largest, spring or fall?

Suggested Films

Amphibians (b&w&col, 11 min) Cor

Frog Anatomy (b&w&col, 17 min) Ind

What is an Amphibian? (b&w&col, 11 min) EBF

MAJOR CONCEPTS

1. Early lungfishes had adaptations that allowed them to invade the terrestrial environment.
2. The seasonal drying up of ponds may have brought about the development of amphibian adaptations.
3. The amphibians are dependent on an aquatic environment for part of their life cycle and are therefore limited in their terrestrial distribution.
4. The toad is the most terrestrial amphibian.
5. Immature or larval amphibians are vegetarians, but the adults are carnivorous.
6. The eggs of amphibians are fertilized externally as they are laid.
7. The two-chambered heart of the larvae becomes three-chambered in the adults. The circulatory system is well developed.
8. Even as adults, many amphibians have webbed feet, enabling them to swim efficiently.
9. The moist skin of an amphibian is richly supplied with blood vessels and aids in respiration.
10. Many amphibians, especially salamanders, have a remarkable ability to regenerate lost or injured body parts.
11. Amphibians are "cold-blooded."
12. Many frogs hibernate and estivate during unfavorable conditions of winter and summer.

ANSWERS TO QUESTIONS FOR REVIEW (Pages 486-487)

1. Early lungfish had jointed, or lobed, fins somewhat resembling legs. It is believed that a fish with legs could perhaps crawl away from a dried-up pond to a pond with water. Thus it is reasoned that the primitive lungfishes, with their lobed fins, were transitional forms between true fishes and amphibians.
2. Thin, moist, flexible skin; feet often webbed; toes without claws; larval forms vegetarian, while the adults are usually carnivorous; heart two-chambered in the larval stage and becoming three-chambered in the adult; eggs directly fertilized; metamorphosis.
3. Three orders: Apoda, Caudata, Salientia. The latter two are represented in the United States.
4. Salamanders resemble lizards in having elongated bodies, a tail and, in most species, short legs. They differ from lizards in having smooth, moist skin without scales and in lacking claws on the toes.
5. The tiger salamander is known as an axolotl in the larval stage.
6. The crimson-spotted newt usually hatches in May into a gill-breathing aquatic larva. In about two months, the larva changes into a land-dwelling stage with lungs. This stage is named the red elf because of the coral-red color. One or two years later, the skin color changes to greenish olive with crimson spots along the sides. Then the newt returns to water and resumes an aquatic life, breathing through its skin while under water and using its lungs at the surface.
7. When an insect nears a frog's mouth, the mouth opens wide, the tongue flips out and catches the insect on its sticky surface, then flips the insect into the mouth cavity.

8. When a frog croaks under water, air is forced from the lungs over the vocal cords, into the mouth, and back to the lungs. This movement can be repeated.
9. The organs of the alimentary canal of a frog are the mouth, esophagus, stomach, small intestine, rectum, and cloaca.
10. The frog's heart consists of a right and left atrium and a ventricle.
11. The conus arteriosus, arising from the ventricle of the frog heart, divides into a left and right branch, then into the carotid arch, aortic arch, and pulmocutaneous arch on the left and right side.
12. Urine flows from the frog's kidneys through ureters which open into the cloaca. Urine passes from the cloaca into the urinary bladder for storage.
13. Changes occurring in the life of a tadpole include: lengthening of the body, appearance of external gills, lengthening of the tail and developing of the caudal fin, disappearance of the horny lip, growth of the fleshy gill covers, appearance of the hind legs, growth of the front legs under the operculum, appearance of the front legs, resorption of the tail, and broadening of the mouth. Many internal changes accompany these external changes.
2. The amphibians have never been successful on land because they cannot survive drying conditions and they are dependent on water for laying eggs and the developing of the young. Thus, they can not survive far from water.
3. The toad is awkward in the water. It lacks the large, webbed feet and powerful hind legs that make the frog a good swimmer. It also lacks the leg development and claws necessary for rapid locomotion on land.
4. During fertilization of the eggs of a frog, sperm are spread over the eggs as they are laid. Most eggs receive a sperm. This is a more efficient method than in the fish, whose sperm are spread in the general vicinity of the eggs during spawning.
5. The tadpole has a two-chambered heart until late in the metamorphosis, gills, lateral line, operculum, tail, and caudal fin. Limbs are lacking early in its life.
6. The frog heart has three chambers, consisting of two atria and one ventricle. The right atrium receives blood from the body circulation, while the left atrium receives blood from the lungs, as in higher animals. Thus, blood may pass through the heart twice in a complete circulation, whereas it passes through the fish heart only once in a complete circulation.

ANSWERS TO APPLYING PRINCIPLES AND CONCEPTS (Page 487)

1. It is believed that the lungfish used the lobed fins to leave drying ponds

Guide to Laboratory Investigations for Chapter 35

INVESTIGATION 35-1

External Structure of the Frog

Scope of the Investigation This Investigation is designed to enable the student to observe the external structures of a frog (pp. 477-479 of the text), and to compare them with the fish, in order to understand how the amphibians have become partially adapted for a life out of water. By comparing the tadpole with the adult frog, the student has visual evidence of the transition from a life in the water to a life on the land (pp. 483-485). If anyone pursues the C-level Part 3, he can demonstrate the amphibian powers of regeneration which he studied on p. 485 of the text.

Approximate time required Part 1 should require approximately 30-40 minutes for the average student to complete.

Part 2 should be completed within a period of 50-60 minutes.

Part 3 is a long-range project requiring several weeks.

A Part 1 External Structure of a Tadpole

Suggestions for procedure. Living bullfrog tadpoles are required for this study. These may be obtained from ponds if available, or may be found in pet stores. The tadpoles should be in various stages of development, but this should present no problem as the bullfrog remains in the tadpole stage two to three years. (If the tadpoles are unavailable from any source, one may use prepared charts of the metamorphosis of the frog or Fig. 35-10 on p. 484 of the text.)

Student observations—answers to questions.

- (a) They have been resorbed.
- (b) Hind legs.
- (c) Not in the early stages.
- (d) Small and somewhat circular.
- (e) It scrapes food from objects in the water.
- (f) It is larger and wider.
- (g) Young tadpoles have eyes on either side of the head; older tadpoles have eyes nearer the top of the head.
- (h) A salamander.

A Part 2 External Structure of the Frog

Suggestions for procedure. Living and preserved frogs are required for Part 2. The living animal should be placed in an aquarium or battery jar for observation. The study of the skin should be made with specimens taken from a preserved animal. However, an interesting demonstration can be set up with a living animal. The frog should be wrapped in wet paper towels or cheesecloth to immobilize it and tied to a small board or piece of corrugated cardboard for support. One hind foot should be left extending over the end of the board or over a hole in the board, with the toes spread out to expose the webbing. This webbing can then be observed under the microscope for evidence of chromatophores, guanin crystals, and capillaries with blood flowing through them. This same demonstration can also be done with the caudal fin of a small fish.

Student observations—answers to questions.

- (a) The frog swims mainly by flexing and extending the hind legs.
- (b) Bronze usually.
- (c) Yes.
- (d) Yes.
- (e) The animal responds quickly by jumping forward.
- (f) The floor of the mouth rises and falls rapidly; the thoracic cavity expands and contracts occasionally.
- (g) Two.
- (h) Yes.
- (i) Air enters the nostrils, then enters the mouth, and passes into the lungs.
- (j) Protects the eye.
- (k) Protects and moistens the eye.
- (l) Somewhat streamlined; more angular than the fish.
- (m) Four.
- (n) No.
- (o) Longer.
- (p) Five.

- (q) Yes.
- (r) Probably not.
- (s) If the pigment is dispersed, the color is dark.
- (t) The pigment is more concentrated in the center of the chromatophore.
- (u) Answers will vary.
- (v) The presence of guanine crystals gives iridescence to the skin; chromatophores give color to the skin.

C Part 3 Regeneration in a Tadpole

Suggestions for procedure. Leopard frog tadpoles in various stages of growth are used for this study. The narcotic solution used may be chloretone 1:2500 or MS 222 1:2500. The animals should be anesthetized by putting them in the narcotic solution. The tail fins should be severed about 4 mm from the tip, varying the angle of the cut with several animals. Note that the tadpoles should be fed a bit of spinach or egg yolk only every other day. After the animals have been allowed to feed for a time, the water should be changed, as it should be on the days the animals are not fed as well. Bacterial pollution is a constant threat to the tadpoles. They should be observed carefully for signs of healing and regeneration, with accurate records kept regarding all developments.

Analysis and conclusions. Students should find that the younger tadpoles regenerated lost tissue more rapidly and more completely than the older ones. The angle of the cut generally has little influence on regeneration. The pigment doesn't develop until several days after the regenerated tissue develops in the tadpoles.

INVESTIGATION 35-2

Dissection of the Frog

Scope of the Investigation This Investigation is designed to acquaint the student with the internal anatomy of the frog as a representative vertebrate. The frog illustrates internal adaptations for land life and provides an excellent introduction to human biology.

Approximate time required Part 1 should require approximately 20 minutes.

Part 2 may require a period of 50-60 minutes.

Part 3 should require approximately 30 minutes.

A Part 1 Structure of the Mouth

Suggestions for procedure. A preserved frog is used for this study. Students will have to clip the jaws at either side of the mouth in order to free the lower jaw and open the mouth.

Student observations—answers to questions.

- (a) At the front of the mouth.
- (b) For catching insects.
- (c) The indented area leaves the glottis free.
- (d) To the lungs.
- (e) To the stomach.
- (f) The inner ears.
- (g) Aid in holding prey.
- (h) The upper jaw.
- (i) They can project the eyes above the surface of the water, or they can be used as an aid in swallowing.

A Part 2 Dissection of the Body Cavity

Suggestions for procedure. Students should remove the skin of the frog as directed in the student manual. Once the initial incisions are made, the skin can be pulled off in several large pieces. In examining the skin for the blood vessels, students should also note the transparent tympanic membrane which was removed with the skin of the head. The organs of the body cavity will be exposed by removing the muscles as directed. However, if this dissection is to run two days because of short class periods, it may be well to have the students merely cut large flaps in the body wall the first day. These flaps of muscle can be secured with pins or rubber bands to enclose and protect the organs while the frogs are stored for further study. Note that the egg masses may have to be removed from mature females before other organs can be studied. Each of the italicized organs discussed in the student manual should be located and examined. The gall bladder will appear green and rather translucent in a preserved specimen. The spleen is a dark reddish-brown body on the mesentery. The rather diffuse pancreas is imbedded in the mesentery attached to the stomach. Students may tend to confuse it with fat bodies. The alimentary canal should be removed as directed and the contents of the stomach and gullet examined. The entire canal should be rinsed out and the linings of the various organs compared. If the heart is not already exposed, it will be necessary to cut through the pectoral girdle and pin back the forelegs. The pericardium should appear as an opaque membrane. If the pericardium has not been previously severed, it should be opened to expose the heart and large vessels. In removing the heart, students should attempt to cut as far from the heart as possible, thus retaining some of the large blood vessel attachments. This is especially important with the venae cavae; students often fail to remove the sinus venosus with the rest of the heart. The organs of the urogenital system are found on either side of the backbone. The ureters are small and coiled. They should not be confused with the oviducts, which are larger. The testes are small bean-shaped yellow or cream-colored bodies lying close to the kidneys.

Student observation—answers to questions.

- (a) It is ridged.
- (b) This increases the surface.
- (c) It appears smooth.
- (d) It is covered with many tiny projections.
- (e) This increases the surface for absorption of food.

A Part 3 Dissection of the Brain

Suggestions for procedure. Dissection of the brain of the frog, as in the fish, is a rather tedious procedure, though not too difficult. The major problem students encounter is cutting too deeply. The bone should be removed gradually, and care should be used to avoid digging into the brain itself. Some students may wish to isolate the entire brain and remove it intact.

Student observations—answers to questions.

- 1. The frog has a longer intestine, specialized digestive glands, and a large intestine.
- 2. Lungs are developed for land breathing, and respiration may take place through the mouth, lungs, and skin membranes.
- 3. Two separate circulations serve the frog's body and lungs. The heart is three-chambered.
- 4. The cerebrum of the brain is larger, thus increasing the amount of higher level behavior.
- 5. The frog's kidneys are more compact and more complex than those of the fish. The skin is also a major organ of excretion.

INVESTIGATION 35-3

Effect of Drugs and Hormones on the Metamorphosis of Amphibians

Scope of the Investigation In this Investigation the role played by hormones and drugs in inducing and controlling metamorphosis in amphibians will be demonstrated. Under controlled laboratory conditions the student observes the rapid transformation of aquatic tadpoles treated with iodine and thyroxine to semiterrestrial adult frogs (pp. 483-485 of text). The role of the thyroid secretions in metamorphosis is further demonstrated by the failure of propylthiouracil-treated tadpoles to metamorphose. The dramatic metamorphosis of the Mexican axolotl when treated with thyroid substances bears out the discussion of feeding experiments on the animals on p. 475 of the text.

Approximate time required The preparation of stock solutions of thyroid-wheat mixture, iodine, and propylthiouracil for use in Part 1 will require 30-40 minutes. Time may be saved by having three students prepare the solutions while others are setting up six aquaria with tadpoles for the experiment. The time required for the completion of the experiment will depend on the kind of tadpoles used. Small tadpoles will metamorphose in approximately two weeks. Bullfrog tadpoles, however, may require four to six weeks. Time will have to be allowed each day for feeding the animals and cleaning the aquaria. Measurement of the animals every fourth day will require 10-15 minutes per animal. Time may be saved in feeding and measuring if a team of students is assigned to observe one group of animals. Then one student can make the measurements while the aquarium is being cleaned. This experiment could be begun previous to the study of the external structures of the frog in Investigation 35-1 and continue through Investigation 35-2.

The axolotl study in Part 2 will require a minimum of three weeks. The stock solutions of thyroxine and triiodothyronine will require 10-15 minutes to prepare. The four aquaria with the axolotls and introduction of the hormones and feeding on the first day will require 15-20 minutes. The feeding and cleaning of the aquaria on alternate days will require 15-20 minutes. Measurement of each animal requires approximately 5 minutes. Time may be saved by assigning a team of students to study one aquarium, as suggested for Part 1. This Part could be correlated with Part 1.

B Part 1 Study of Effects of Drugs and Hormones on Frog Metamorphosis

Suggestions for procedure. The thyroid and propylthiouracil tablets will have to be purchased on prescription from a physician. The tadpoles may be purchased from a biological supply house or fish hatchery or the students may collect their own. Small tadpoles must be at least one inch long. Bullfrog tadpoles will be from two and a half to three inches long. If tapwater is used, it should first be aerated or let stand to allow for evaporation of the chlorine.

The student should measure all of the animals at the beginning of the experiment. The use of millimeter graph paper taped to the bottom of a Petri dish facilitates the observation and measurement. The change is not great enough to use a ruler, and holding the animals and measuring with a metric ruler is rather difficult.

The water must be changed every day to prevent bacterial growth that may kill the tadpoles. Feed the animals only every other day. Pablum or shredded lettuce may be substituted for the spinach or hard-boiled egg yolk. The kind and amount of food should be uniform for the different groups.

The first change will probably be a decrease in the length and width of the caudal

fin. As the gills are covered by the operculum, the tadpole will begin to come to the surface for air. The growth of the hindlimbs occurs before the fore limbs emerge. Have the student look for the buds of the forelimbs that are visible under the thin skin. There will be a gradual change in the texture of the skin; the eyes will bulge and the mouth widen, as the animal becomes adapted to a semiterrestrial habitat.

All the animals will not respond in the same manner to the treatment. The age of the animals may vary, although they are the same size, and the concentration of the thyroid substances and iodine may have been too great. Sometimes the tissues literally burn up.

The propylthiouracil-treated animals will continue to grow, becoming very large tadpoles with dark-spotted skins. There should be no evidence of metamorphosis. Using propylthiouracil is comparable to doing a thyroidectomy. This should demonstrate that the thyroid gland plays a vital role in metamorphosis.

Student observations—answers to questions.

- (a) Shortening of the caudal fin.
- (b) Those treated with thyroid-wheat mixture.
- (c) Tail shortens, body begins to lengthen, hindlegs emerge, forelegs emerge, eyes bulge, mouth widens.
- (d) Not necessarily.
- (e) Tadpoles may be too young, concentrations of the thyroid substances may vary, and normal variations occur so that the pattern is not always the same.
- (f) Probably.
- (g) Pollution of water, dosage of substances too large so that the tissues were oxidized.
- (h) Should be those treated with thyroid-wheat mixture.
- (i) The level of thyroid was increased and metabolism increased
- (j) It is a component of the thyroid hormone.
- (k) It inhibits metamorphosis.
- (l) Large body and caudal fin; skin thick, dark, and covered with spots.

Interpretation. The animals treated with thyroid substances and iodine metamorphosed or showed evidences of metamorphosing. The propylthiouracil blocked the activity of the thyroid in some animals, and they failed to metamorphose.

B Part 2 Effect of Thyroid Hormones on the Metamorphosis of the Mexican Axolotl

Suggestions for procedure. Thyroxine and triiodothyronine tablets may be purchased on prescription. Living axolotls are often difficult to obtain, but some of the companies that sell living specimens may handle them. The liver may be purchased at the grocery and frozen for feeding the animals. Thyroid gland tissue may be obtained from slaughter houses or dissected from freshly killed frogs, rats, or other laboratory animals. Small pieces of the tissue are fed to the axolotls in the same manner as the frozen liver. The aquaria should be kept in a cool place, so that the water temperature does not exceed 70°F.

Students probably will be very surprised at the rate at which the gills atrophy. They should also be able to see the formation of eyelids, the bulging of the eyes, and the thickening of the skin. The experimental animals will probably molt during the experiment, while the control will not. Molting is a characteristic of the adult salamander. When metamorphosis begins, the animals may not eat because the caudal fin and gill tissue are being used in metabolism.

The control will continue to grow as the experimental animals stay the same size. Mature larval axolotls are much larger than metamorphosed salamanders.

Student observations—answers to questions.

- (a) Skin thin and white, caudal fin present, eyes on the side of the head and lack eyelids, gills present.
- (b) The one fed thyroid gland tissue.
- (c) Gills were shorter.
- (d) The one treated with triiodothyronine.
- (e) Caudal fin disappeared, skin tough and thick, yellowish in color, eyes rotated to top of head and were bulging, eyelids present and molting had occurred, gills lacking.
- (f) It has thin, pink skin, eyes on side of head, no eyelids, large caudal fin, heavy body, gills.
- (g) The control is a mature larval form, since metamorphosis did not occur.

Interpretation. Iodine, which is a component of the thyroid hormone, is lacking in the water. Since the animal cannot produce this hormone, it remains in its larval state. In areas where iodine is available, the animal can produce the thyroid hormone necessary for metamorphosis.

Chapter 36

The Reptiles

Since reptiles are similar to amphibians in many characteristics of their internal structure, we have emphasized external characteristics and natural history in this chapter. The discussion begins with the dinosaurs, a topic of general interest. Reports on several of the better known dinosaurs, such as *Brontosaurus* and *Tyrannosaurus*, accompanied if possible with strip films, Kodachrome slides, or projected pictures will provide an interesting introduction to the reptiles. The story of the *Sphenodon*, a rare reptile older even than the dinosaurs, is included in this chapter.

Superstitions and false ideas which lead to fear of harmless snakes should be discussed as a means of developing more favorable attitudes toward these valuable vertebrates. In the interest of conservation, students should be taught to recognize the poisonous snakes of their region so as to avoid them, but should be urged not to destroy or molest the harmless species. The snake is an especially interesting study in adaptation.

Whenever possible, snakes and lizards of various kinds should be kept in terraria in the classroom. A goose-necked lamp may be used to provide warmth, and sand, rocks, leaves and twigs may provide a natural background. The feeding of snakes is an interesting aspect and one which the

students won't forget, but many teachers prefer to demonstrate this after school. Lizards may be fed mealworms.

Turtles may be easily maintained in the classroom, and provide a valuable experience in observation. Properly controlled, a turtle race may provide the students with some figures for interesting calculations as to the speed of travel on land.

Special reports on the natural history of the reptiles should be encouraged. A highly practical project would be the demonstration of a snakebite kit and presentation of data concerning mortality from venomous snake bites in the past few years.

P. 494, Fig. 36-4: Explain the diagram and the milking of snakes on snake farms. The poison is used for the preparation of antivenom. Snake charmers remove the fangs.

P. 495, Fig. 36-5: Teeth point backward to allow prey to pass down but be caught if the prey tries to get away.

P. 495, right column: Digestive juices dissolve bones. Sometimes hairs and the pads of the feet are left.

P. 500, left column: The legless lizard, or "glass snake," of the southern United States has already been mentioned. Iguanas are edible and are sold in the markets of Mexico.

P. 502, right column: Edible turtles

are canned or used fresh. Pet turtles kept in proper conditions and not fed solely on "ant eggs," but on other fare, do well in captivity. The diet may include raw ground beef, apples, lettuce, and mushrooms, depending on the species. Turtles with painted shells should not be bought because they eventually die as a result of the painting.

P. 504, left column: The plastron has a place in Chinese history. It was subjected to heat and the direction and extent of the cracks produced were used for divination. Shells showing these marks from ancient times have been unearthed.

P. 504, right column: Reptiles have many uses for man besides their place in nature as predators and prey. Magazine or newspaper advertisements show these uses. Snakes, lizards, alligators, and tortoises are used to make belts, pocketbooks, shoes, and jewelry like tortoise shell combs, earrings, and pins.

Suggested Films

Dinosaur in the Wall (b&w&col, 9 min)
Ind

Dinosaurs (col, 28 min) AIBS McGraw-Hill

From Water to Land (col, 28 min) AIBS McGraw-Hill

Reptiles and Their Characteristics (b&w&col, 11 min) Cor

What is a Reptile? (b&w&col, 18 min)
EBF

MAJOR CONCEPTS

1. The development of an amniotic egg with a shell, internal fertilization, and a body covering of scales which resists drying, contribute to the successful terrestrial existence of the reptiles.
2. Fossil evidence indicates that the reptiles did not become truly terrestrial until late in the Carboniferous period.
3. Reptiles became the most important animals on the land, in the air, and perhaps even in the sea during the Mesozoic era.
4. Many reptiles are now extinct.
5. Reptiles with feet have claws on the toes.
6. Gills are never present and reptiles breathe with lungs.
7. Metamorphosis does not occur in the life cycle of the reptiles.

8. Reptiles are "cold-blooded."

9. Turtles, lizards, snakes, alligators, and *Sphenodon* demonstrate the diversity of forms of reptiles.

10. Reproduction among various kinds of reptiles may be oviparous or ovoviviparous.

11. Although many snakes are harmless, some are poisonous.

ANSWERS TO QUESTIONS FOR REVIEW (Page 505)

1. Reptiles had eggs with shells which freed them from the necessity of returning to the water for reproduction. The skin of reptiles resists loss of water by evaporation.
2. Fossil remains are generally limited to hard parts such as bones and teeth. Some of the important differences between amphibians and reptiles are in the soft tissues, which do not become fossilized.
3. *Brontosaurus*, the largest of the dinosaurs, was a plant-eating dinosaur. It measured 75 feet in length, was 15 feet high, and weighed 30 tons or more. It had a very long neck, balanced by an equally long heavy tail. *Tyrannosaurus*, the tyrant lizard, was a flesh-eater. It walked erect on powerful hind legs and balanced its body with its long tail. Its front legs were short and equipped with powerful claws which could tear its prey to shreds. It was 50 feet long and 20 feet high. Its jaws were powerful and rimmed with double-edged teeth three to six inches long.
4. a. Squamata (snakes and lizards); b. Testudinata (turtles and tortoises); c. Crocodilia (crocodiles and alligators); d. Rhynchocephalia (*Sphenodon*).
5. a. Body usually covered with scales; b. skin dry, not moist and slimy; c. feet, if present, having claws on the toes; d. eggs internally fertilized and, if laid, having a protective shell; e. no metamorphosis; f. gills never present, as both young and adults breathe with lungs; g. body temperature changing with environment ("cold-blooded").

6. The most unusual characteristic of the *Sphenodon* is the parietal eye in the top of its head.
7. The snake's tongue is primarily an organ of smell.
8. Snakes capture their prey by catching it in the mouth and swallowing it alive, by squeezing it to death, or by poisoning it.
9. The quadrate bone allows the jaws to drop downward and forward at the hinges. A ligament in the front of the lower jaw allows the halves of the jaw to be thrust forward independently.
10. The most common method of locomotion is the lateral undulating motion. The snake's body moves from side to side, forming broad curves. The snake pushes against the irregularities of the ground, which give it a grip for moving forward. The caterpillar movement in which the snake crawls in a straight line is also used. Several scutes are pushed straight forward in several sections of the body. The posterior edge of the scutes grip the ground and the body is pulled forward by waves of muscular contraction. Snakes of the sandy deserts employ the side-winding means of locomotion. The body is twisted into an S-shaped loop and is raised from the ground except for two or three points of contact.
11. Cobras, coral snakes, vipers, and pit vipers. The cobras are almost entirely limited to the tropics of Africa and Asia. Some species of the cobra spit a fine spray of poison which can travel several feet with surprising accuracy and can cause blindness if it enters the eye. The coral snakes, which are beautifully colored and relatively small, are found mainly in the southern United States. While their venom is very potent, they seldom cause death because they have very short fangs which are unable to penetrate heavy clothing. The vipers include all poisonous snakes in Europe, Africa, and Asia that do not belong to the cobra family. They have large hollow fang teeth that are held in an erect position when the mouths open but are folded flat when the mouth is closed. The pit vipers are found mainly in North and South America. They can be distinguished from the true vipers by the presence of temperature-sensitive pits located on either side of the head. These pits are so designed that the pit viper can accurately strike at any prey that produces heat.
12. The pit of pit vipers is a temperature-sensitive organ. It senses infrared rays and thus determines the position of any prey that produces heat.
13. Neurotoxin affects the parts of the nervous system that control breathing and heart action. Hemotoxin destroys red blood cells and breaks down the walls of small blood vessels.
14. Crocodiles have been successful because they can breathe even when in the water with their mouths open. Thus, they can remain concealed until they reach their prey.
15. The turtle has been able to survive through the years because of its box-like shell into which many of them can draw the head and feet. Many can swim very efficiently. The horny toothless beak is an efficient shearing mechanism which permits the animal to eat meat or plants. Turtles can remain submerged for long periods of time.

ANSWERS TO APPLYING PRINCIPLES AND CONCEPTS (Page 505)

1. The scaly covering of a reptile is better suited to life on land than the skin of an amphibian because it gives better protection and reduces water loss from the tissues. Claws on the toes permit climbing and running on land. The lungs are better developed for air breathing than those of amphibians. Reproduction does not require water, as it does in the amphibians.
2. The eggs of fish and frogs are laid in water and are not subject to dry-

- ing out. Reptile eggs are usually buried in sand or soil and would dry out if they were not shell-covered.
3. Certain dinosaurs may have starved to death when the plants on which they fed died out as conditions of the earth changed. Many were destroyed by carnivorous mammals. Earth and climatic changes undoubt-

edly took a toll of many dinosaurs. It is also believed that dinosaurs did not possess brains sufficiently large in proportion to their brawn.

4. Rare animals have survived on islands because they are free from natural enemies. Similar organisms on larger land masses were exterminated ages ago.

Chapter 37

The Birds

Birds exhibit some of the most interesting adaptations and specialized structures in all of animal life. Their study is an introduction to outdoor biology as well as a possible hobby. And it is an important lesson in conservation.

Two general conditions are apparent in the study of the anatomy of the bird—lightness and power. Feathers, air-filled bones, toothless beak, and air sacs are adaptations for life in the air. Powerful wing and shoulder muscles, highly developed digestive organs, and a large heart relate to the enormous power required for flight. The streamlining of the body, form and movement of the wings in flight, and use of the tail as a rudder illustrate principles of aerodynamics.

The study of bird diets and feeding habits introduces the economic value of most birds. Conservation should be stressed throughout this chapter. You may wish to expand the study of bird conservation, bird laws, and the work of bird societies at this time. If so, refer to Chapter 53, pp. 723-741 in MODERN BIOLOGY.

Activities carried on in this chapter will vary with locality and available facilities. They may include a trip to the zoo, bird walks, keeping a list of birds, especially during migration, projects in field identification of birds, banding, raising birds, and making charts for the bulletin board.

P. 508, Fig. 37-2: While students use open books, a stuffed bird can serve as a model for pointing out the parts. Use the Appendix for classification and characteristics.

P. 508, left column: Birds use their tails as brakes. In winter when alighting on

ice-rimmed water, they may misjudge the distance and end up skidding along the ice on the end of their tails.

P. 509, Fig. 37-3: Have on hand a collection of different kinds of feathers. Show feathers from several body areas (peacock feathers are always eye-catching). Interlocking of the barbules is shown by ruffling a feather and then smoothing it back to its original shape. Look at the feathers through a hand lens or a three-dimensional microscope.

P. 510, left column: Have a bird skeleton available. A student may be willing to prepare one from a chicken as a special project.

P. 510, right column: Feathers cover a bird's body in definite patterns. Sketch on the board a rough diagram of the ventral pattern and point out that when a bird ruffles the feathers before sitting on eggs, it is to bring the bare skin with its maximum heat in contact with the eggs.

P. 511, left column: Wing motion is shown in slow motion in films along with other bird habits. A bird bander can tell about his hobby or may know a person who does banding and is willing to have visitors.

P. 511, Fig. 37-5: Stamp collectors can bring in examples of birds, other animals, and plants depicted on stamps. Australia and New Zealand show unusual fauna on their stamps. Switzerland has a series on flowers. Stamp collecting can be both educational and enjoyable.

P. 514-515, Fig. 37-7: Tell about the natural history of these birds. Besides the caption suggestion, deal also with tails. One good example shown here is the wood-

pecker, whose tail feathers are stiff and help in propping him on the tree.

P. 516, left column: Pigeons take in food, partially digest it, and then regurgitate it for the young as "pigeon's milk."

P. 516, Fig. 37-7: Compare the respiratory system of active birds with that of the reptiles. The song box is called the syrinx.

P. 517, Fig. 37-9: Compare the bird brain with the fish brain on p. 468 and the frog brain on p. 482 as to size and function of parts.

P. 517, right column: In preparation for the next chapter, have reports on the speed of birds and mammals. Students on farms can tell about chicken habits. Mating is called treading. If a discussion on this topic is handled properly, there should not be any embarrassment.

P. 518, left column: Rural students or those who spend summers on a farm can tell about the preparation of eggs for marketing, candling, the place of lime in a chicken's diet, and the effect of insufficient lime. The peck order in birds is a good topic for discussion. This is carried on up through the animal kingdom including in man, who seeks social status.

P. 518, Fig. 37-10: The reproductive system can be shown by dissection of a chicken. The structure of an egg can be illustrated by the use of a raw egg and board diagram.

P. 519, Fig. 37-11: Incubate a series of eggs and open one at two-day intervals to follow development. Remind students that only a small part of the egg will develop into the chick. The remainder is food for the embryo. Students always ask about blood spots they find in eggs. These are caused by small hemorrhages in the tube through which the egg must pass. They do not spoil the egg. Remind them how eggs are used to cultivate viruses for vaccines.

P. 520: Nest building exemplifies instinctive behavior. It ranges all the way from the complicated nest of the oriole to no nest as in the cowbird. A collection of old nests would help here. Pictures or board sketches can be used to show the difference in eggs—from the pea-sized hummingbird egg to the ostrich egg equal to one dozen hen's eggs. The number of eggs laid can be increased by taking the

eggs away as they are laid. Experimenters have tried this and a bird that normally lays about 15 eggs can be made to lay 90!

Suggested Films

Birds and Mammals (col, 28 min) AIBS McGraw-Hill

Birds and Their Characteristics (b&w&col, 11 min) Cor

What is a Bird? (b&w&col, 17 min) EBF

MAJOR CONCEPTS

1. Scientists believe the first birds appeared more than 200 million years ago.
2. *Archaeopteryx*, the earliest bird, is known by a fossil and indicates a curious mixture of lizard and bird characteristics.
3. Flight is not necessarily a bird characteristic. Many birds are flightless and some mammals fly.
4. The presence of feathers is a distinguishing characteristic of birds.
5. Birds are well-adapted for flight.
6. Birds are oviparous and fertilization is internal.
7. Birds are "warm-blooded."
8. The heart of a bird contains four chambers, and there is no mixing of oxygenated with nonoxygenated blood.
9. Molting rids the bird of broken feathers, but it may serve to give the bird protective coloration.
10. Some knowledge of the life and feeding habits may be gained from examining the feet and beaks of birds.
11. The capacity of the lungs is increased by air sacs that extend into the chest area, the abdomen, and into the cavities of the larger bones.
12. Food stored in the crop helps to provide energy for the rapid metabolic rate of birds.
13. The excretion of uric acid conserves water.
14. The bright plumage of male birds during the mating season attracts females.
15. The number of eggs incubated is indirectly proportional to parental care.

ANSWERS TO QUESTIONS FOR REVIEW (Pages 520-521)

1. If it were not for the feather impressions, scientists would have

- classified the *Archaeopteryx* as just another reptile skeleton.
2. Birds have retained two conspicuous characteristics from their reptile ancestors: scales on their legs and feet and claws on their toes.
 3. Feathers; porous, air-filled bones; the forelimbs developed as wings; body supported on two limbs; horny, toothless beak; and air sacs extending from the lungs.
 4. The plumage of a bird includes down feathers, serving as an insulation; filoplumes; contour feathers, which cover the body and give it a smooth outline and coloration; and quill feathers, used in flight.
 5. With the beak, birds transfer oil from the oil gland at the base of the tail to the feathers. This aids in the buoyancy of water birds.
 6. The shoulder muscles used in flight by the bird are attached to the breastbone.
 7. Most flightless birds have succeeded in life only because they live in areas that are free of predators. Many became extinct after the arrival of man. Some have developed powerful legs and keen vision.
 8. The feet of swimming birds are webbed, those of climbers are four-toed (two in front and two in back), those of waders have long toes for balance. Thus, we can determine the habitat of a bird from its feet. The sharp curved beak of a hawk readily identifies it as a carnivore and distinguishes it from the heavy crushing beak of a seed eater.
 9. The air sacs of a bird increase the

capacity of the lungs and are believed to eliminate excess heat from the bird's body.

10. The bird heart is large and is composed of four chambers. Birds have a rapid pulse and circulation.

ANSWERS TO APPLYING PRINCIPLES AND CONCEPTS (Page 521)

1. Birds have achieved success as a group because their variations adapt them to many different types of life. Because they can fly they can change their environment as conditions require. Since their diet and means of feeding are varied, all forms do not compete for the same food supply. The coloration of many birds protects them from enemies.
2. Flightless birds are not considered primitive because they are similar to other birds and some have exceptionally strong legs and keen vision. Their wings may be developed for other uses like swimming.
3. The rate of respiration in birds is much faster than any of the other vertebrates studied so far and their consumption of food is great because of the increased rate of metabolism.
4. *Warm-blooded*, or *homoiothermic*, is a term applied to birds, because their temperature remains fairly constant because of lungs and air sacs which eliminate excess heat.
5. More eggs are produced by birds that have precocial young than by birds whose young are altricial and require a great deal of care.

Chapter 38

The Mammals

The study of mammals in this chapter brings the study of vertebrates to a climax. We begin the chapter with a discussion of those characteristics that set mammals apart from other vertebrates. The student should become thoroughly familiar with these characteristics and will, no doubt, think of himself in reviewing them. Mam-

mals are highly adapted organisms, as illustrated by variations in size, diet, limbs, teeth, and other characteristics. Mammalian behavior is variable, also.

Since students are familiar with many mammals, discussions of behavior on the levels of instinct and conditioned reaction are desirable. Students can discuss instinct-

ive behavior in mammals in such acts as care and defense of the young, self-defense, construction of homes, and migration. Animal training illustrates conditioned reactions. Evidence of intelligence in mammals is an interesting phase of the discussion of behavior.

Much of the chapter is devoted to getting acquainted with mammals. Thirteen orders are included in the discussion. A full-page illustration of mammals appears on p. 527 of MODERN BIOLOGY. The orders of mammals are listed, with examples, in the Appendix of the text. Many teachers expand the study of mammals with an illustrated lecture or series of reports, using Kodachrome slides, strip films, or pictures projected from mammal books with an opaque projector.

Bulletin boards, preserved, and living specimens of various mammals are important. Mice, moles, and other small mammals may be housed in terraria. Gophers may be kept in narrow terraria filled with soil and occasionally stocked with carrots. When the earth is damp, the gopher may be seen digging his tunnels. It is recommended that as many of these personal experiences with animals be provided as is possible. The students should be encouraged to bring in specimens, even if you can provide for them only for a few days and then must release them.

P. 523, left column: Bats are the only mammals that can actually fly. The flying squirrel and flying phalangers merely glide. The flying squirrel has a membrane stretched between his front and hind legs which enables him to glide.

Mammals have long guard hairs and soft underfur. In processing, the long hair is often removed leaving only the underfur. Synthetic furs may have long fibers added to simulate real guard hairs. The giraffe has seven cervical vertebrae but they are longer than those of other mammals.

Students may wish to report on the monotremes. The male platypus has a spur for fighting, the female has no true nipple for nursing her young. The young suck a group of hairs which stick together when milk is secreted. These act as a nipple.

P. 525, right column: Have a report given on the common rat, its place in history, habits, and destructiveness. It is one of

man's outstanding enemies and is persistent despite the warfare waged against it.

P. 526, table: Pictures, films, sketches, and Fig. 38-5 can illustrate the table. Also, tell something of the natural history of the animals in the illustration. Have students consult the Appendix to classify themselves as to kingdom, phylum, class, order, family, genus, and species.

P. 530, right column: When coyotes are eliminated, their prey increase in number and become pests to man. Man must consider the balance when he tries to eliminate the so called varmints.

P. 532, left column: Cows get hardware disease by swallowing bits of wire, nails, etc. when they graze. This may kill the cow by puncturing its stomach. A magnet is fed to the cow, remains in the first stomach, and attracts metal objects, thus preventing them from traveling further.

P. 534, Fig. 38-11: This heart diagram can be used to discuss similarities and differences in the hearts of lower vertebrates.

P. 536, Fig. 38-12: Use this illustration for a review of brain structures and functions.

P. 538: Have students list as many uses of mammals to man as they can think of. The following is a partial list: a. Used as food. As the development of crop plants changed man's nomadic habits, so did domesticated mammals change man's food habits. b. Skins used as shelter—nomads today still use them. c. Used as beasts of burden. d. Hunted and used for hunting. e. Skins provide clothing. f. Used in scientific studies. g. Rabbits used in pregnancy tests. h. Kept as pets. i. Used for pleasure—photography of wild animals is a special challenge.

Suggested Films

What is a Mammal? (b&w&col, 14 min) EBF

MAJOR CONCEPTS

1. Compared with other animals mammals are a recent form of life, appearing about 60 million years ago.
2. Mammals have bodies covered with hair and most are viviparous.

3. Young mammals are nourished by milk secreted by mammary glands.
4. Much of the success of mammals is attributed to the highly developed cerebrum.
5. Mammals breathe by lungs and breathing is aided by a diaphragm.
6. Only the left aortic arch is present and leads from the four-chambered heart to an efficient circulatory system.
7. Mammals are "warm-blooded."
8. Although many marsupial mammals are living today, most are placental.
9. The diverse forms of mammals adapt them to various environments and diets. Many are either herbivorous or carnivorous, but several are omnivorous.
10. Cell dependence accompanies the tissue specialization and organ development in mammals.
11. The basis for mammalian structure and function may be found in the lower vertebrates.
12. Much can be learned about the behavior and mental abilities of the vertebrates by comparing their brain structure.
13. Mammalian reproduction is efficient and parental care of a few offspring insures their survival.

ANSWERS TO QUESTIONS FOR REVIEW (Pages 538-539)

1. *Eohippus*, three-toed horse, sabretoothed tiger, mastodon, mammoth, and ancient species of rhinoceros, camel, and wild pig.
2. The mastodon is one of the most ancient North American mammals.
3. Refer to page 523.
4. The duckbill and spiny anteater lay eggs which hatch externally.
5. Marsupials have pouches in which the immature young are nourished after birth. Placental animals nourish the young inside the uterus and at birth they are in a more advanced stage of development.
6. The armadillo has a protective armor covering its body.
7. Lagomorphs have four incisor teeth in each jaw rather than two as in rodents.
8. The cetaceans have a torpedo-shaped

body and fishlike tail and forelimbs which provide locomotion. They use lungs for breathing but can hold their breath for a long time. The young are born with the ability to swim, and the mothers push them to the surface immediately for their first breath of air. They can withstand sudden pressure changes and can dive to great depths.

9. Mastodons and mammoths.
10. Fox, wolf, bear, wolverine, coyote, raccoon, ermine, and puma are some North American carnivores.
11. The teeth of ungulates are adapted for cropping and grinding vegetation. Some have elongated limbs and feet that enable them to run fast. Hoofs, which are modified toenails, help to absorb the shock of running. Many have horns or antlers for protection.
12. Primates have superior brain development and well-developed arms and hands. Their fingers are used for grasping, and one or more fingers or toes are equipped with nails. Most primates can walk erect if necessary.
13. "Warm-blooded" refers to the fact that some animals can maintain a constant body temperature regardless of the variation in the environmental temperature.
14. The bird's heart is closest to the mammalian heart in structure.
15. The cerebrum is most highly developed in the mammalian brain.
16. Marsupials are born in such an immature stage that they need further protection and nourishment while they are developing. These are afforded them in the pouch or marsupium.
17. Larger mammals produce smaller numbers of young and provide parental care over a longer period.

ANSWERS TO APPLYING PRINCIPLES AND CONCEPTS (Page 539)

1. Regulation of the internal environment has allowed the mammal to

find a wide variety of habitats in which natural selection favored certain variations. Therefore, mammals show many adaptations.

2. The fish has a small heart composed of two chambers. The heart of the amphibian has two atria so that oxygenated and deoxygenated blood are separated. However, in the ventricle the blood is mixed and from here some goes back to the lungs and some goes to the body. The ventricle of the reptile heart has a septum which partially divides it. In the mammalian heart and in the bird heart, the septum completely divides the ventricle to prevent mixing of oxygenated and deoxygenated blood. The heart is, then, a double pump,
3. The capacity for learning is possible because of greater development of the cerebrum and the lengthened period of immaturity during which an animal can learn. The animal's capacity for learning makes training possible. During training the animal learns to associate a signal with a given activity, after which praise or a reward is given.
4. In mammalian reproduction, the eggs are fertilized internally. The embryo is implanted on the wall of the uterus and receives food and other substances from the mother during development, thus greatly reducing the mortality before birth.

Guide to Laboratory Investigations for Chapter 38

INVESTIGATION 38-1

Dissection of the Fetal Pig

Scope of the Investigation This Investigation is designed to familiarize the student with the internal anatomy of a mammal. The organs of the fetal pig are not too different from those of the human. Thus a dissection of the fetal pig makes an excellent laboratory counterpart to the study of human anatomy the student finds on pp. 551-657 of the text.

Approximate time required The time required for this dissection will vary with the type and purpose of the related study. If the pig is dissected in conjunction with the study of mammals in general, perhaps at the conclusion of a study of Chapter 38, the dissection might well be conducted over a period of two to four 50-60 minute laboratory periods, depending on the thoroughness desired. If, on the other hand, this dissection is made in conjunction with the study of human biology covered in Chapters 40-47, the laboratory work can be divided into several different sections to be correlated with the study of the various chapters. Thus parts of this dissection could be carried out on one or two days per week over a period of several weeks.

B Part 1 Dissection of the Fetal Pig

Suggestions for procedure. Students should be equipped with a complete set of dissecting instruments and a preserved fetal pig. Biological supply houses offer pigs that have the veins and arteries injected with colored latex, thus providing excellent specimens for dissection and study of the circulatory system. However, most schools may find the cost of such animals would prohibit their general use, and may be able to provide only one injected specimen for demonstration purposes. For general student use, most schools may prefer to obtain their specimens from a local slaughter house. These must be preserved by injecting an 8% formalin solution into the esophagus, anus, and umbilical vessels. The smaller specimens (6-8 in.) preserve much better than those nearer full term. There are a number of guides to the fetal pig in print. Some of these should be made available to the students if the fetal pig is to be studied

in much detail. The student manual has outlined the usual sequence of systems for study. However, the order of study can vary if it is to be correlated with the study of the human. This is also an excellent opportunity to point out the structural modifications present in the fetal condition.

If students are to study the reproductive systems, they may use the following procedure:

Female reproductive system. The female reproductive tract should have been exposed with the removal of the alimentary canal. The *ovaries* are a pair of small, oval-shaped bodies lying near or slightly posterior to the kidneys. Each ovary is supported by a fold of mesentery. The reproductive tract of the female pig is more or less Y-shaped. Each anterior arm of the Y is formed by the narrow, convoluted oviduct, or *Fallopian tube*, lying lateral to the ovary. Each tube begins in a hoodlike expansion with fluted lips. Spreading these lips apart will reveal the opening (*ostium*) of the tube. The rest of each arm of the Y lies posterior to the ovary and is greatly expanded into the *horn of the uterus*. The two horns then converge to form the *body of the uterus*, thus forming the stem of the Y. It should be called to the students' attention that the bicornate uterus of the ungulates represents incomplete fusion of the posterior ends of the oviducts. The fusion process extends from a state of two separate uteri in rodents and rabbits to complete fusion into a single simplex uterus in primates, including humans. The uterus narrows somewhat at the *cervix*, and the *vagina* proceeds posteriorly through the pelvic canal, lying between the urethra and the large intestine. Carefully separate these structures to discover the point where the vagina and the *urethra* unite. From this point the two form a common passage, the *urogenital sinus*, to the opening on the body surface. It should be noted at this point that in humans and other primates the vagina and urethra do not unite into a common passage, but open independently on the body surface.

Male reproductive system. The *testes* of most mammals undergo a descent so they lie in a sac of skin, the *scrotum*, outside of the body cavity. The testes may be exposed by cutting open the scrotum on either side. The testes lie in a pair of cordlike *inguinal sacs* which were formed by an out-pushing of the abdominal wall during the descent of the testes from the abdominal cavity into the scrotum. The *testis* is a relatively large body lying in the posterior part of the sac. The *epididymis* is a band-shaped mass of coiled tubules and connective tissue attached to the surface of the testis. The *ductus deferens* leaves the tail of the epididymis and passes through the inguinal sac and through the body wall via an opening known as the *inguinal canal*. The ductus deferens then enters the peritoneal cavity for a short distance, and with the ductus deferens of the opposite side, enters the *urethra*, thus forming the *urogenital canal*. A small *prostate gland* and paired *Cowper's glands* may be found surrounding part of the ductus deferens and urogenital canal, respectively. The *penis* encloses that part of the urethra lying outside of the pelvic canal. It is enclosed in a sheath which lies along the ventral side of the body. The urogenital canal lies along the ventral surface of the penis, imbedded in a column of spongy tissue called the *corpus cavernosum*.

Interpretation. The structures present in the fetal animal that the student should discuss would include the umbilical vessels, the allantoic bladder, abdominal vein, ductus arteriosus, and the lungs, which are completely collapsed.

Suggested References for the Teacher—Unit VI

Books

Barth, L. G. *Embryology*. Rev. ed., Holt, Rinehart and Winston, New York, 1953

Bullough, W. S. *Vertebrate Reproductive Cycles*, 2nd ed. John Wiley & Sons, New York, 1961

- Burt, William and Grossenheider, Richard. *A Field Guide to the Mammals*. Houghton Mifflin Co., Boston, 1952
- Burton, Maurice. *Animal Legends*. Coward-McCann, New York, 1957
- Cochran, D. M. *Living Amphibians of the World*. Doubleday and Co., New York, 1961
- Colbert, E. H. *Dinosaurs: Their Discovery and Their World*. E. P. Dutton & Co., New York, 1961
- Eddy, Samuel. *How to Know the Fresh-Water Fishes*. W. C. Brown Co., Dubuque, Iowa, 1958
- Gilliard, E. T. *Living Birds of the World*. Doubleday and Co., New York, 1958
- Gary, J. *How Animals Move*. Cambridge University Press, New York, 1953
- Griffin, D. R. *Listening in the Dark*. Yale University Press, New Haven, Conn., 1958
- Hall, E. Raymond and Kelson, Keith R. *The Mammals of North America*. The Ronald Press Co., New York, 1958
- Hamburger, V. *A Manual of Experimental Embryology*. University of Chicago Press. Chicago, 1960
- Hanson, Earl D. *Animal Diversity*. Prentice-Hall, Englewood Cliffs, N. J., 1961
- Articles*
- Anderson, Sydney, "Return of the Beaver." *Natural History*, October, 1964
- Banfield, A. W. F., "Grizzly Territory." *Natural History*, March, 1964
- Bogert, Charles, M., "How Reptiles Regulate Their Body Temperature." *Scientific American*, April, 1959
- Breeden, Kay, "Frutivorous Fliers." *Natural History*, May, 1964
- Ebert, James D., "The First Heartbeats." *Scientific American*, March, 1959
- Ferster, Charles, B., "Arithmetic Behavior in Chimpanzees." *Scientific American*, May, 1964
- Gray, Sir James, "How Fishes Swim." *Scientific American*, August, 1957
- Gray, George W. "The Organizer." *Scientific American*, November, 1957
- Griffin, Donald R., "More About Bat Radar." *Scientific American*, July, 1958
- Grundfest, Harry, "Electric Fishes." *Scientific American*, October, 1960
- Kortlandt, Adriaan, "Chimpanzees in the Wild." *Scientific American*, May, 1962
- Lerner, A. B., "Hormones and Skin Color." *Scientific American*, July, 1961
- Minton, Sherman A. Jr., "Snakebite." *Scientific American*, January, 1957

UNIT SEVEN

THE BIOLOGY OF MAN

Interest in the study of the human body has increased greatly in recent years. Radio and television programs, books, periodicals, and newspapers present advances in medical science, surgery, human physiology, health measures, problems of radiations, space frontiers to be conquered, and treatment of disease almost as they occur. Terms and procedures as well as anatomical knowledge of the human body, known only to the physician a few years ago, are almost household words today. Thus the modern student approaches his study of human biology with considerable interest, motivation, and background knowledge.

The scope, emphasis, and methods of teaching this unit will probably vary with the health instruction in your high school. If biology precedes the study of health in the curriculum, you will probably correlate the anatomy and physiology included in this unit with applications to the study of health. This correlation will prevent duplication in content of the two courses and will allow greater enrichment of the health course. In some schools, the unit in human biology comprises much of the health instruction. In others, where a semester course in health is required, the study of human biology may become an enrichment program, growing beyond the scope and coverage of the health course.

We begin the study of man with anthropology. The current theories of man's development are presented as ideas which have grown from our increasing knowledge. The study of human biology then proceeds with a presentation of human tissues, organs, and systems. This approach emphasizes the interrelation of the various body parts as a functional unit. The following chapters explain systems which provide the tissues with substances essential to life, and which involve the removal of waste.

The nervous system and sense organs introduce the control and communication systems of the body. Their study is followed by the effect of alcohol, narcotics, and tobacco on the human organism. The social implications of these substances are also discussed. Another coordinating system that controls many vital functions is the endocrine glands presented in the next chapter.

The last chapter deals with continuation of the human species. A modern biology course requires an understanding of reproduction and development. The development from the zygote to a complex multicellular being proceeds in a regular, organized manner and is treated as such in the discussion of embryology.

OUTCOMES

The study of this unit should result in:

1. Knowledge of early man and how scientists attempt to fit together small bits of information to visualize life in the past.
2. Better understanding of the human body as a complex unit of life.
3. Understanding of the similarities and differences between the human body and that of other organisms, especially higher vertebrates.
4. Acquaintance with the tissues, organs, and systems composing the human body.
5. Knowledge of the interrelation of systems and processes in supplying the tissues with food and other essential substances and in removing wastes accumulated by cell activity.
6. Appreciation of man's nutritional dependence on other living things.
7. Awareness of man's superiority among living things resulting from the high development of the human nervous system.
8. A knowledge of the body and its processes which should result in better health practices and understanding of health problems.
9. Understanding of problems resulting from the use of alcohol, narcotics, and the excessive use of tobacco.
10. Knowledge of the human reproductive systems.
11. Knowledge of human embryology and fetal development.

Chapter 39

The History of Man

Man's structure allows him to assume an upright posture, thus freeing his hands for grasping. The location of his eyes provides him with good depth perception. These, together with a highly developed nervous system and large cerebrum, have allowed him to become biologically superior. His capacity to think, read, write, and talk by the use of symbols enables him to pass on his knowledge from generation to generation.

Anthropologists studied fossil evidence of

man before communication was as advanced as it is today. From the data offered by only fragments of the past, conjectures are made regarding primitive man. Since these theories have been held by scientists at various times, they have been presented for discussion. Point out to the students that theories have been presented and discarded many times throughout the evolution of scientific thought. Many superstitions of today (such as spontaneous generation) were once theories.

We do have evidence, however, of primitive manlike organisms and the study of these and the way in which they are dated is an interesting part of biology. Discussions can center around the communication methods before the development of a language, visualizing food habits, family life, the beginning of agriculture, and conclusions that can be drawn from fragments of skeletons or fossils representing life in the past.

P. 543, right column: Darwin's original writings, *The Voyage of The Beagle* and *Origin of Species*, can be read in part by the teacher or students who make reports.

P. 546: Much so-called primitive art is appropriate today. Cave and rock paintings in France, Spain, Australia, and Africa are records of the past. The Sahara Desert is rich in prehistoric rock engravings and rock-paintings discovered in 1933. Books on anthropology, archeology, and art have material to help both the teacher and students delve further into the cultural history of man.

Suggested Films

Evolution of Man (col, 28 min) AIBS McGraw-Hill

Rocks and the Record (col, 28 min) AIBS McGraw-Hill

The Story of Prehistoric Man (b&w&col, 11 min) Cor

MAJOR CONCEPTS

1. The organs and systems of the human body closely resemble those of other mammals.
2. The structural similarity of man and the other primates is especially striking.
3. The chemical secretions of man and other mammals are similar. The digestive enzymes are the same and many hormones of other mammals may be used in treating deficiencies in the human.
4. Man has significant differences from other mammals that have allowed him to become biologically superior.

5. Man's knowledge, observation, inquisitiveness, and imagination have enabled him to theorize about his origin and development.

6. Fossils can be dated if the age of the strata in which they were found is known, or by computing the amount of carbon-14 in the specimen.

7. Recent discoveries indicate that manlike creatures may have lived one and three-quarters million years ago.

8. Fossils often give us clues as to how primitive man lived, whether he had communication, and what he ate as well as clues to his appearance.

9. All people living today belong to the species *Homo sapiens*.

10. Agriculture may have developed from a settled life.

ANSWERS TO QUESTIONS FOR REVIEW (Pages 549-550)

1. Man is the only animal with truly upright posture. He has a shortened and flattened pelvis which holds the abdominal organs. His hands are free and the action of the thumb opposes that of the fingers. The fingers are highly sensitive to touch and are grooved so that smooth objects can be grasped. The location of eyes give a sense of depth, and man is intelligent.
2. Charles Darwin believed that a primitive primate, perhaps back ten million years, gave rise to the various groups of primates. Thus the monkey, gorilla, chimpanzee, orangutan, and gibbon are all specialized forms. When Darwin pointed out the similarities between these forms and man, some people interpreted his comparisons as suggesting that man evolved from monkeys. This was not his intent.
3. The finding of an old skull links the past with the present. Archeologists can date the skull and, by careful examination, determine the age and sex of the individual, the shape of its head, the food it consumed, and perhaps even the way

it died and whether it made and used tools or lived in a society. It would also indicate the brain size.

4. The jaw structure indicates whether its owner had the capacity for speech.
5. The type of environment that occurred in a given area thousands of years ago can be determined by the fossil remains of plants and animals in that area. The types of food remains around a primitive campsite indicate the climate and nature of the surroundings.
6. The diet of primitive man has been determined by campsite remains and by the structure and wearing surfaces of the teeth.
7. Fossils can be dated by determining the relative ages of the layers of the earth. Then, by knowing from which layer a fossil was removed, we have an estimate of its age. The radio-carbon method is more recent. In living organisms there is about one carbon-14 atom to one trillion carbon-12 atoms. Since the half-life of carbon-14 is 5,568 years, the amount of carbon-14 left in a fossil can be used to determine its age.
8. *Australopithecus* is believed to have looked like modern apes without the pointed fanglike teeth. He is believed to have had an upright posture.
9. *Pithecanthropus erectus* is the Java man. He is believed to have lived 500,000 years ago. He had a slanting forehead and heavy brow ridges. He walked erect and his brain was only about half the size of modern man's. He is believed to have made tools and used fire.
10. Mongoloid type, which originated in Asia; Negroid type of Africa; Caucasoid type, which originated in Europe; and the Australoid type of Australia and Ceylon.

ANSWERS TO APPLYING PRINCIPLES AND CONCEPTS (Page 550)

1. Under usual conditions tropical forests would not provide good fossils because conditions are so ideal for a variety of living forms that a dead organism is eaten by others and decay occurs very rapidly.
2. Intelligence of a primitive man can be judged from the skull, indicating brain size, and by the tools he made and used. If the same types of tools are found in several different age layers, we might believe that communication of some kind had occurred.
3. It has been theorized that once tool making began, natural selection did not favor the longer canine teeth which were used for killing animals for food.
4. Java man had a slanting forehead and heavy brow ridges and his brain was only half the size of modern man's. Neanderthal man's forehead sloped backward from heavy brow ridges and his brain was as large or larger than modern man's. Cro-Magnon man had a high forehead and lacked the heavy brow ridges of more primitive man. Scientists believe that he was more intelligent than Neanderthal man. Modern man has a high forehead with a large brain capacity.
5. Perhaps much of their communication was by way of their paintings left on the walls of their caves. The drawings represent animals living at the time and weapons used.
6. A settled life may have given man a chance to become more familiar with his surroundings and, therefore, to notice the areas where certain edible plants grew. He may have learned to take out the undesirable plants (weeds) and allow only the edible varieties to flourish.

Chapter 40

The Body Framework

This chapter begins with an outline of the general structure of the human body—its cells and tissues, organs, and systems. The body tissues are listed. If prepared slides of various human tissues are available, demonstration microscopes can be set up in connection with this study. If not, a collection of photomicrographs from biological supply house catalogs and magazines will provide many details for discussion. An opaque projector or a microprojector may be used in class discussions.

Following this introductory study, the skeletal and muscular systems are introduced. Slides and pictures may be used, but disarticulated bones and a skeleton will be very helpful if available. Reports on the current theory of muscular contraction, the growth of bone, and the functions of bone may provide experience for some students. Bones may be obtained from a butcher shop and studied in class. The locations of muscle attachments can be found and stresses discussed. Food supply to the bone can be better understood when a bit of the periosteum is pulled away to expose small blood vessels entering the bone.

Demonstrations involving the kymograph and muscle contraction studies are interesting. Arrangement of muscle fibers should be related to the function of various muscles, such as sphincters, sheet muscles, skeletal muscles, blood vessel muscles, and cardiac muscles.

P. 552, Fig. 40-1: The long cooking of tough cuts of meat is done to break down the connective tissue shown here.

P. 557, left column: Point out the difference between a simple, compound, and greenstick fracture. Call on students who have had first aid.

P. 558-559: Use a large wall chart for a teaching guide and a prepared mimeographed sheet. The text may be used as a guide for checking labels.

P. 562, right column: Tendons obtained from fresh meat show the appearance of this tissue. A fresh chicken leg may be used to show the action of tendons.

Suggested Films

Living Solid (b&w, 30 min) Ind

The Human Body: Muscular System (b&w&col, 13½ min) Cor

The Human Body: Skeleton (b&w&col, 11 min) Cor

MAJOR CONCEPTS

1. The human body is composed of cells and their products.
2. The cells of the body can be placed into four groups based on structure and function.
3. The general form of the human body is similar to that of the other vertebrate animals.
4. Bone tissue is a combination of living cells and their products and mineral deposits.
5. Some lower vertebrates have cartilaginous skeletons, but in man, most of the cartilage is replaced by bone.
6. Bones grow along lines of stress.
7. The various bones of the human body are connected by several different kinds of joints.
8. When activated by a nerve impulse, ATP supplies the energy for contraction.
9. Three general types of muscle cells are found in the human body.
10. The skeletal muscles that move joints of the trunk and limbs are always arranged in pairs.

ANSWERS TO QUESTIONS FOR REVIEW (Page 564)

1. Tissues are groups of cells all performing the same function, and they are grouped into an organ which performs a definite function. The organs that are grouped together for a certain function compose the system. For example, the muscle is a tissue in the stomach which is an organ and comprises part of the digestive system. Each part contributes to the whole and thus to division of labor.

2. The three body cavities are the abdominal, thoracic, and cranial. The abdominal cavity is enclosed by the pelvis below and the diaphragm above. It contains the stomach, intestine, liver, spleen, pancreas, kidneys, and ovaries in the female. The thoracic cavity is bounded by the diaphragm below and by the rib cage. It contains the heart and lungs. The cranial cavity is surrounded by the bones of the skull and contains the brain.
3. The functions of bones are: providing support and form for the body (the cranium, femur, tibia, pelvis, sternum); providing a place for the attachment of muscles (the femur, humerus, tibia, and fibia); protecting delicate organs (the pelvis, ribs, and bones composing the cranium).
4. The Haversian canals carry nourishment to the living cells of the bony layer by means of blood vessels that connect with those of the outer membrane.
5. Ligaments, composed of strong connecting tissue, surround many joints and keep them together as well as prevent free movement. Many joints are surrounded by a connective tissue, the synovial membrane, which maintains a fluid in the joint so that it is lubricated for ease of movement.
6. The hip and shoulder joints are ball-and-socket joints. The bone of the upper arm ends in a ball which fits into a socket of the shoulder girdle. The hip joint is formed by the ball of the femur fitting into the socket of the pelvis. The attachment of the ribs to the vertebrae is an example of a partially movable joint. Here only slight movement occurs during respiration. Joints of the knee and elbow are hinge joints, as they move only in one plane. Immovable joints are found in the bones of the cra-

nium where, during growth, the bones have fused.

7. Muscles are often classified as smooth, striated, and cardiac, depending on the appearance. Muscle tissue may also be classified as involuntary, voluntary, and cardiac, depending upon the control. Muscle tissue may also be classified according to location, such as skeletal and cardiac.
8. Muscles are often found in opposing pairs in the body because when a flexing action occurs, it is necessary to have a control over the extending action.
9. When a striated muscle contracts, it shortens and becomes thicker in the middle.

ANSWERS TO APPLYING PRINCIPLES AND CONCEPTS (Page 564)

1. An internal skeleton does not provide external protection. This protection is given by defensive behavior, made possible by a highly developed nervous system and sense organs.
2. Other factors involved in producing good teeth and healthy bones are the assimilation of the minerals provided by the diet and the obtaining of additional vitamin D required for the assimilation process.
3. The walking cast puts a broken bone under limited stress during the healing period, speeding up the repair process.
4. The heart of lower animals is much less complicated than that of higher animals. When only a small part of the heart is removed and placed in a nutrient solution, it will continue to beat. Cardiac muscle is unique and demonstrates contractility, automatism, and rhythm.

Guide to Laboratory Investigations for Chapter 40

INVESTIGATION 40-1

Study of Bone

Scope of the Investigation In this Investigation the student examines a long bone to determine how it is adapted for support and attachment of muscles (pp. 557-558 of the text). Examination of the blood vessels in the periosteum and a slide of an Haversian system should give a better understanding of how the living cells in the bony layer are nourished. The presence of organic as well as inorganic matter in bone is demonstrated. The student actually observes the substances that compose bone as he analyzes a demineralized bone and bone ash. If any students do the C-level activity, they will learn about the deposition of calcium phosphate in bone and other tissues.

Approximate time required Part 1 will require 50-60 minutes for the examination of bone and microscopic study of an Haversian system. An additional 30 minutes should be allowed for the drawings.

Six to eight days will be required to remove the mineral content of the bone in Part 2. It will take 40-50 minutes to analyze the organic matter that is left following demineralization. This Part might be started the same day the long bone is examined.

Part 3 can be completed in an hour and a half if a small piece of bone is used.

Part 4 is a long-range activity and probably should be carried out after school.

A Part 1 Examination of External and Internal Structure of a Long Bone

Suggestions for procedure. The tibia of a cow or sheep may be obtained from a slaughter house or butcher shop. Since most schools do not have a bone cutter, someone in the class might ask the butcher to section some leg bones lengthwise. In examining the long bone, note the difference in color and structure between the articular cartilage on the ends of the bone and the periosteum in the center. The students might cut into the periosteum and peel a section back to see the double layer of tissue and the network of blood vessels.

Student observations—answers to questions.

- (a) Protects the ends of bones by forming a smooth surface so that they can slide against each other.
- (b) It is living tissue and has metabolic requirements.
- (c) They are raised places that resemble scars.
- (d) Surface.
- (e) To provide maximum strength.
- (f) Interior of bone.
- (g) Receives the stress put on it during movement.
- (h) Marrow—red in the diaphysis and yellow in the ends near the epiphysis.
- (i) Contains fat cells, blood vessels, and may produce blood corpuscles during blood loss or certain diseases.

B Part 2 Demineralization of Bone

Suggestions for procedure. Pieces of rib bone of a hog or young steer may be obtained from slaughter houses or the butcher.

Since dissolving bone gives off an unpleasant odor, put the setup in a hood, if available. The student should handle the bone with a pair of tongs while washing the hydrochloric acid from it. The bone should bend easily if all the mineral content has

been dissolved from it. The filtrate will also have an unpleasant odor and should be heated in a hood or in a room where the windows can be opened. The dissolved bone filtrate may appear brownish in color because of the presence of organic carbon.

Student observations—answers to questions.

- (a) Probably will be yellowish.
- (b) Organic carbon.
- (c) Sticky and leathery.
- (d) It contains the organic matter of bone; the inorganic matter was dissolved out by the hydrochloric acid.

Interpretation. A bone from which the mineral content has been removed, leaving only the organic matter, bends easily. Thus the organic matter is responsible for the flexibility of bone.

B Part 3 Analysis of Bone Ash

Suggestions for procedure. Pieces of rib bone of a hog or young steer, obtained from slaughter houses or a butcher, should be cut into one-inch sections for burning. The bone will begin to crack as the organic matter is removed and will ultimately be reduced to ash.

In the reaction of the ammonium hydroxide and ash filtrate, there will be very little of the phosphate in the filter paper, but it should be saved. The filtrate is used to demonstrate the presence of chlorides and calcium carbonate. When acetic acid is added to the residue of phosphate, some of it may not be dissolved. Then test for the presence of iron as directed.

Student observations—answers to questions.

- (a) A black color.
- (b) Carbon is present and turns black when burned.
- (c) Greyish.
- (d) Phosphates in bone are white; the grey color is due to the small amount of carbon mixed with the phosphates.
- (e) The material fizzes and forms bubbles; the ash begins to dissolve.
- (f) Probably is.
- (g) Probably not.
- (h) Calcium carbonate residue may not be pure; iron may be present.
- (i) Answers will vary.

Interpretation. Bone is made up of carbonates, phosphates, and iron.

C Part 4 Relative Distribution of Radioactive Phosphorus in the Organs of the White Rat

Suggestions for procedure. The teacher must be thoroughly familiar with the handling of radioactive substances before doing this experiment or assigning it to a student.

The nature of radioactive materials requires careful preliminary planning. The phosphorus³² in 10-microcurie amounts may be purchased from several sources that supply radioactive isotopes. P³² has a half-life of two weeks. Thus, its radiation intensity is reduced 50 percent every two weeks so that it should be ordered in sufficient time and used immediately.

Always use rubber gloves when handling the isotope and injected rats. The rat can be injected by putting it on its back, holding its head down with one hand and putting a knee on the lower part of the abdomen, leaving one hand free to make the intraperitoneal injection. The animal may be sacrificed by putting it in a closed container with a wad of cotton saturated with ether.

All materials used in the experiment must be cleaned thoroughly in soap and water. The remains of the animals should be burned.

Analysis and conclusions. Blood had the highest count for phosphorus uptake after two hours because the element was readily absorbed into the blood stream from the peritoneum. At the end of the experiment blood had the lowest uptake, while bone had the highest, as would be expected.

INVESTIGATION 40-2

Study of Muscle Contraction

Scope of the Investigation In studying the characteristics, functions, and control of smooth, skeletal, and cardiac muscles simultaneously in this Investigation, the student should obtain a better understanding of their similarities and differences. The three kinds of muscle are obtained from a pithed frog. The technique for pithing is given in the Investigation.

The comparison of the behavior of the three types of muscles in a Ringer's solution is a dramatic demonstration of initiation of contraction and of responses (pp. 561-563 of the text). The control of smooth and cardiac muscle by the two parts of the autonomic nervous system (p. 619 of the text) is demonstrated as the muscles are treated with acetylcholine and adrenalin. The regulation of skeletal muscle activity is also demonstrated.

Approximate time required Pithing the frog and removing the gastrocnemius muscle, the heart, and stomach tissue will require a minimum of 30 minutes. Time may be saved if the teacher piths the frogs before class. Treating and observing the muscles in Sections 2 and 3 will require 20 minutes. The preparation of the apparatus in Section 4 will require 10-15 minutes. This may be done outside of class. The experimental activity and observations will require 20 minutes.

B Part 1 Study of Muscle Contraction

Suggestions for procedure. This study may be used as a demonstration, the class may be divided into teams, or an individual student might do it as a project.

The frogs may be purchased from companies that supply living specimens. It is a good idea to have extra frogs since students may have difficulty in pithing them, and some may fail to respond in Section 4 because of muscle fatigue. Adrenaline and acetylcholine may be bought through a physician or from drug supply houses in 20-ml vials of a 1:1000 concentration. To prepare the 1:10,000 concentration, add 11 ml of distilled water.

Be careful not to leave the frog in the etherizing bottle too long or it may die. Emphasize the fact that the pithing merely destroys the spinal cord or central nervous system; it does not kill the frog. It is necessary to have living tissue for this Investigation. The 0.7% Ringer's solution is used because it is similar to the frogs' normal body fluids. The muscles should be put in the Petri dish containing Ringer's solution immediately after they are removed from the frog.

Pith another frog for Section 4, which should be done as a class demonstration. Be sure to keep the muscle moist with the Ringer's solution. Practice with the regulation of the induction coil before class will help to regulate it to deliver a strong enough stimulus to produce a shock.

Student observations—answers to questions.

- (a) No.
- (b) The gastrocnemius muscle requires a stimulus; it is a voluntary muscle.

- (c) It contracts.
- (d) By nerve impulses.
- (e) The rate will vary; the heart should contract more rapidly than the stomach.
- (f) The stomach will contract more frequently than the heart, which may finally stop entirely.
- (g) The heart will contract more frequently than the stomach muscle in the adrenalin solution.
- (h) The sympathetic nervous system releases adrenalinlike substances and the parasympathetics release acetylcholine. Each muscle is regulated by both systems, and their effects are antagonistic.
- (i) The muscle will do more work when normal body conditions are simulated.
- (j) The response is dependent upon the strength of the stimulus. Also, muscles do not always give the maximum contraction of which they are capable.

Interpretation. Smooth and cardiac muscle are under the control of substances released by the autonomic nervous system. Each of the muscles is regulated by the sympathetic and parasympathetic nervous system; the effects of the two are antagonistic. Adrenalin accelerates the heart and inhibits the stomach; the heart is inhibited and the stomach accelerated by acetylcholine.

The skeletal muscle must be stimulated before it will respond. The degree of response is dependent upon the intensity of the stimulus. As the strength of the stimulus increases, the muscle contraction becomes stronger.

Chapter 41

Nutrition

The interrelation of living things becomes more apparent in the study of foods. The classes of foods discussed in this chapter should be traced back to their origin in chemical activity of the green plants. The uses of different kinds of foods in body activity, growth, and maintenance make a balanced diet necessary.

Reports or discussions on the chemical nature and activity of enzymes, chemical composition of foods, absorption of food substances, and activities within cells whereby food is used in synthesis of other substances or for energy will add to the understanding of nutrition. It would be well to renew the chemical basis of life (Chapter 3) here and to study cellular nutrition (Chapter 6) again in relation to extracellular digestion.

P. 568, right column: Cellulose is also called roughage. Examples are fruit peels, husks of whole grain cereals, and flours.

P. 570, table: A bulletin board chart can be made with colored cutout pictures or drawing of foods rich in certain food substances, foods needed daily, etc.

P. 571, Fig. 41-1: Draw a diagram of the digestive system on the board and have the students sketch one at their desks. Have students test themselves by writing the names of the parts as you point to them. Then have them correct their papers as you go over the parts again. This self-test can be varied by adding questions about functions. Students like this type of test because they are not graded with recorded marks. The test can act both as a teaching device and a review.

P. 573, right column: If students practice making certain sounds and use a mirror, this will give them an idea of the importance of the tongue in language. A report on methods of teaching deaf children to talk emphasizes the practical application of the knowledge of how sounds are made. The story of Helen Keller and the play and film "The Miracle Worker" both demonstrate how a deaf mute learns to communicate.

P. 574, left column: Discuss the function of the varied kinds of teeth in the human mouth and stress the importance of

care for the baby teeth. Students can obtain dental charts from their dentist and indicate the condition of their own teeth with cavities, fillings, and caps. A large tooth model or chart are both good for explaining structure. A collection of different kinds of human teeth can be mounted in plaster for a permanent teaching aid. Extracted teeth for this may be provided by dentists. A human skull will show how teeth are fitted in the jaw. Various dental problems like braces and malocclusion can be discussed. A collection of teeth from other animals may serve for comparison. Students sometimes find weathered jaws with teeth and these make the lesson more meaningful if used by the teacher for showing types of jaws, teeth, relation of teeth to food, and how the jawbone is nourished.

P. 574, right column: Bring in fresh tripe and pass it around. A dissertation on gourmet methods of cooking it is in order.

P. 575, left column: Rennin is commercially used in junket and rennet puddings. This makes a good class demonstration.

P. 578, left column: As a summary of what digestion takes place where, have an outline written on the digestion of a ham sandwich, listing all the ingredients and what change takes place in these ingredients in the various organs. See review question 8.

Have students keep track of all food consumed in two days including gum and vitamins. In table form, they can outline the caloric value and analyze food content for vitamins, protein, carbohydrate, and minerals. Tally the total amount of Calories consumed and compare caloric consumption with caloric need. Students can do either a quantitative analysis or one in which they merely indicate the presence of food substances. Figuring the caloric content can be done in class if each student has a good reference. These student records are valuable for discussing diet: what is a good diet? how can sweets be added to the diet without using refined sugar? how can a lunch carried to school be varied? Most young people consume too many carbohydrates and need to have suggestions made on how to obtain variety (use celery, carrot sticks, dried fruits, fresh fruits, cheese, and boiled eggs).

Suggested Films

Digestion of Foods, 2nd Edition (b&w&col, 18 min) EBF

Foods and Nutrition (b&w, 11 min) EBF

Ingestion and Digestion (col, 28 min) AIBS McGraw-Hill

The Human Body: Nutrition and Metabolism (b&w&col, 13½ min) Cor

MAJOR CONCEPTS

1. Food is any substance which, when absorbed into the body tissues, yields materials for the production of energy, the growth and repair of tissue, and the regulation of life processes, without harming the organism.
2. Six classes of substances are considered as foods.
3. Organic nutrients are foods that have been formed by cells of another organism and contain the element carbon.
4. The energy values of foods are measured in heat units.
5. Vitamins are organic compounds that act as catalysts.
6. Vitamin deficiency produces diseases characteristic of the vitamin involved.
7. Tissues cannot use most foods in the forms in which they are ingested.
8. Digestion chemically breaks down complex molecules into simpler ones. This process begins in the mouth.
9. The various types of teeth are adapted for different functions.
10. Protein digestion begins in the stomach in an acid environment.
11. Digestion continues in the first part of the small intestine, where the contents are made alkaline.
12. Absorption of digested foods occurs in the small intestine.
13. Absorption of water occurs in the large intestine.
14. Each step of digestion is controlled by a specific hydrolytic enzyme and occurs outside the cells.
15. The secretions of various glands, as well as those of cells lining the digestive tract, function in the digestive process.
16. Villi greatly increase the absorption surface of the small intestine.
17. Rhythmic waves force the contents through the digestive tract.

ANSWERS TO QUESTIONS FOR REVIEW (Page 580)

1. a. Water is vital to the maintenance of life as it is a solvent for substances and a medium for transportation in the body; b. carbohydrates may be stored or used for energy; c. fats also may be stored or used for energy; d. proteins furnish the body with building blocks from which an individual body may make many substances; e. minerals are essential for growth and for such structures as teeth and bones; f. vitamins are necessary substances which the body cannot synthesize but are essential to proper body functioning.
2. Generally, foods must be simplified chemically and changed to soluble substances during digestion.
3. The mouth, esophagus, stomach, small intestine, large intestine (colon), and rectum.
4. The tongue serves as an organ of speech, an organ of taste, aids in chewing, accomplishes swallowing, and keeps the inner faces of the teeth clean.
5. The parotid salivary glands lie on each side of the face, below and in front of the ears; the submaxillary glands are within the angles of the lower jaws; and the sublingual glands lie in the mucous membranes beneath the tongue.
6. A tooth cut lengthwise shows the enamel layer of the crown, the cementum covering of the root, the dentine layer, and the pulp cavity, containing the nerve and blood vessels.
7. All starchy foods should be chewed thoroughly to permit the ptyalin in saliva to change the starch to maltose sugar.
8. As the milk, butter, and ham enter the stomach, the pepsin changes the protein portion to peptones and proteoses. Rennin coagulates the casein in the milk. In the small intestine, the proteoses and peptones are changed to peptids by the trypsin of the pancreas. Erepsin from the

intestinal glands further changes the peptids to amino acids. The fat globules in the milk and butter and the fat of the ham are emulsified by bile. Lipase changes the fat to fatty acids and glycerin. The bread is acted upon by the ptyalin of the saliva and the starch is changed to maltose. If all the starch is not acted upon in the mouth, the amylase from the pancreas changes it to maltose in the small intestine. The maltase of the small intestine changes the maltose to glucose.

9. Bile contains waste substance from the liver, a secretion which emulsifies fats, steapsin of the pancreatic fluid, and an agent which neutralizes the hydrochloric acid produced in the stomach.
10. A large amount of water enters the blood from the large intestine. In addition, it excretes indigestible matter.

ANSWERS TO APPLYING PRINCIPLES AND CONCEPTS (Page 580)

1. A deficiency can occur if the vitamin is not being assimilated properly, either because of disease or drugs that have been used.
2. Food is mixed with hydrochloric acid in the stomach. In the small intestine it becomes alkaline through enzyme action.
3. Rhythmic contractions of the walls of the large intestine should move the contents at such a rate that water absorption can take place normally. If the contents move through too rapidly, they are excreted in a watery condition, resulting in diarrhea. If the movement of the contents is delayed, too much water may be absorbed, resulting in constipation.
4. Sour milk has already undergone casein coagulation and contains acid. Both of these conditions are produced in the stomach. Thus part of the stomach function has been performed externally.

Guide to Laboratory Investigations for Chapter 41

INVESTIGATION 41-1

Chemistry of Digestion

Scope of the Investigation This Investigation introduces the study of extracellular enzymes as catalytic agents in the chemical phase of digestion (p. 576 of the text). As the student performs each of the tests under controlled conditions, he will observe the action of enzymes in saliva, gastric fluid, and pancreatic fluid. The study of fat digestion by pancreatic fluid demonstrates that enzymes often require the presence of other substances as a medium for their activity. The influence of temperature on enzyme action is also demonstrated.

Approximate time required The five Sections in Part 1 will require an hour and a half if all students perform every test. To save time and materials, the class should be divided into teams assigned to the Sections. Section 1 will require 20 minutes. Sections 2 and 3 will each require 20 minutes for their preparation, but the prepared tubes will not be examined until the next class period. Section 4 can be completed in 20 minutes. Section 5 will require 50-60 minutes.

Part 2, which requires 50-60 minutes, should be combined with Part 1 and assigned to a team of students.

A Part 1 Action of Digestive Enzymes

Suggestions for procedure. The various substances containing the enzymes and the sodium taurocholate can be purchased from biological supply houses. The student can bring the crackers, hard-boiled egg, and lard or butter from home. Check the content of the crackers as they may contain sugar.

After the student has demonstrated that starch but not sugar is present by using the iodine and Fehling's tests, he is ready to test for the presence of a starch-splitting enzyme in saliva. It may be necessary to review the iodine test for starch and the Fehling's test for sugar. The students may react with some distaste when asked to contribute the saliva, but one member of the team will probably cooperate. Washing the mouth out is essential, since the presence of chewing gum will alter the results. There will probably be a positive iodine test in tube 3 and a negative sugar test in tube 4, since the saliva does not split the starch molecules quickly. The piece of cracker must be chewed thoroughly, since mechanical action aids in the breakdown of the cracker and hastens the action of the starch-splitting enzyme in the saliva. The iodine test in tube 5 should be negative and the Fehling's test in tube 6 should be positive. The results of this test should give a better concept of the relationship between the mechanical and chemical phases of digestion.

The litmus test on the pepsin and hydrochloric acid solution demonstrates that it is acidic. Point out that the fluids of the stomach are normally acidic. The tubes are left overnight in a warm place, as near body temperature as possible, because the conditions for digestion should be similar to those within the stomach. Digestion should occur in the tube containing egg white because egg white is protein and pepsin is a protein-splitting enzyme. Tubes containing the cracker and lard or butter should be negative.

The litmus paper test on the solution of artificial pancreatic fluid should show that the fluid is neutral. The pH of fluids is critical because each enzyme functions only within a given pH range. Leave the tubes prepared in this Section overnight and in a warm place to simulate body conditions. The student should observe that digestion has occurred in all three tubes, demonstrating the presence of starch, protein, and fat-splitting enzymes.

The study of litmus milk in Section 4 is further demonstration of the presence of protein and fat-splitting enzymes in pancreatic fluids. The color change to pink indicates the presence of acid, as amino acids and fatty acids have been formed.

A check of the pH of the medium in each of the three test tubes in Section 5 should show that they are neutral. A check of the tubes with litmus or Hydrion paper after they have stood in the water bath (40°C) for 30 minutes should show that the solution in tube 1 is very acid, neutral in tube 2, and acid in tube 3. The difference in degree of acidity is due to the presence of bile as an activator in tube 1 and its absence in tube 3.

Student observations—answers to questions.

- (a) Tubes 1 and 2 serve as controls.
- (b) The fresh unchewed cracker contains starch. Introducing saliva into the tubes containing starch does not necessarily reduce the starch to sugar. The mechanical breakdown of the cracker speeds up the reducing action of the enzyme in the saliva.
- (c) The enzyme in pepsin splits protein but not starch or fat.
- (d) Hydrochloric acid provides the proper medium for the enzyme to act.
- (e) Water does not contain enzymes—it is the control. Pancreatic fluid contains starch, protein, and fat-splitting enzymes.
- (f) Pancreatic amylase.
- (g) People usually do not chew food enough to mix it with saliva.
- (h) The solution to which the pancreatin powder was added turned pink, indicating an acid reaction. The enzymes in the pancreatin powder split the fat into fatty acids and the protein into amino acids.
- (i) The solution was acid.
- (j) The solution remained neutral.
- (k) The solution was acid.
- (l) Fat digestion occurred in tube 1, resulting in the formation of fatty acids. The bile in tube 1 increased the activity of the enzyme in the pancreatin. Bile does not digest fats and pancreatin was missing in tube 2, so it remained neutral. The enzyme in pancreatin split the fat molecules, forming fatty acids and changing the solution from neutral to acid. The solution in tube 1 was more acid than the solution in tube 3 because bile increases the activity of lipase.

A Part 2 Effect of Temperature on Enzyme Action

Suggestions for procedure. Do not rush this activity. The results of the Benedict's test are graphic, demonstrating that enzymes have an optimum temperature for activity and that they are more effective at body temperature than at either extreme. Fehling's solution may be substituted for the Benedict's.

Student observations—answers to questions.

- (a) Solution in tube in water bath and room temperature shows a color change from green to orange with Benedict's solution; a change from green to red with Fehling's solution. No change occurs in the solutions held in the refrigerator and incubator.
- (b) Heating to high temperatures or greatly lowering the temperature inactivates pancreatic amylase.

Chapter 42

Transport and Excretion

In introducing the circulatory system, it is interesting to compare the distribution of digested food materials in the human to that of a single-celled organism and then to that of a sponge. A complex organism like man must keep its cells bathed in fluids which are pumped through vessels and into the tissue spaces. The chemical and cellular nature of blood should be related to its various functions.

The major blood vessels may be observed in the "Trans-Vision" between pp. 584 and 585 of MODERN BIOLOGY. A bulletin board and diagrams will increase the student's understanding of the anatomy of the circulatory system.

A comparison of the vertebrate heart will provide the students with a review showing the increase in the efficiency of circulatory systems from the lower forms to the mammals. A heart model or wall chart showing the heart will aid in explaining the pumping cycle. Point out the location and function of the valves in maintaining blood pressure.

The function of the blood in excreting metabolic wastes and maintaining water concentration in the body is aided by the kidneys. A chart or bulletin board of a nephron and its associated vessels will enhance the explanation of this filtering unit. If students prepare the bulletin board, you may instruct them to indicate water, salts, nitrogenous wastes, sugar, and other foods by various colored circles. The substances can be shown leaving the blood in the capsule and returning to the blood from the tubule.

Reports on the comparison of the kidneys of various animals from marine, fresh-water, and terrestrial environments will bring out the adaptive value of differences in the function of kidneys.

The excretory function of the skin should be discussed, as well as the vital role of perspiration in the body's cooling system. The absorption of heat during evaporation can be demonstrated by pouring alcohol on the skin. The excretory role of the lungs in releasing carbon dioxide and

water vapor should be emphasized. It is also important to discuss the role of the large intestine, gall bladder, and liver as organs of excretion.

P. 582, left column: Since some students may have donated blood to the Red Cross, tie this in with the work on blood. Mention was made earlier of freeze-drying for food preservation. Plasma has been prepared this way for a long time. Discuss the use of plasma and saline and glucose solutions.

P. 583, right column: When a patient enters the hospital to undergo surgery, a blood sample is taken to determine clotting time as well as blood type and Rh factor. Driving licences in some states have a place to indicate blood type.

P. 587, Fig. 42-3: Refer again to the autoanalyzer which does blood tests, including typing at the rate of 60 per hour and gives a written record of the results.

P. 589, Fig. 42-5: Heart muscle is edible and in Peru it is considered a delicacy if cut into small pieces and broiled.

Have a stethoscope available for student use. Have students learn in class how to take the pulse rate. They can compare the rate while sitting or after exercising, and the rates of boys and girls. At home they can keep an account in table form, with conclusions reached, after taking the pulse while sitting, lying down, just after exercise, after a hot bath and large meal.

P. 589, Fig. 42-5: Follow circulation of both systemic and pulmonary circulations and include the valves.

P. 590, Fig. 42-6: Bring pieces of an artery and vein to class. Use this as an opportunity to discuss spare parts now being made for the human body: Dacron tubing to replace weak blood vessel walls (in aneurysm) heart valves, prosthetic devices to replace lost limbs. Have students look up accounts of efforts made to help victims of the thalidomide drug disaster.

Reports may be made on anemia, leukemia, hemophilia, varicose veins, erythroblastosis, and other circulatory disorders and diseases.

P. 591, right column: What are black and blue marks? The old-fashioned remedy for a black eye was to place a steak on the eye. Now the steak is eaten instead!

P. 593, right column: A blister contains lymph which acts as a cushion between the skin and source of irritation. This is very evident in foot blisters.

P. 595, Fig. 42-9: Get a kidney from the butcher and dissect it. Refer to the frog kidneys.

P. 596, right column: Discuss kidney grafts. Urinalysis can be done in the laboratory.

P. 597, Fig. 42-11: Discuss the skin and its care. Hair of man and other animals is an interesting topic for discussion because students always have questions about baldness, care of the hair and the skin. Eczema and acne, causes and treatment, interest students.

Suggested Films

Circulation (col, 28 min) AIBS McGraw-Hill

The Blood (b&w&col, 16 min) EBF

The Human Body: Circulatory System (b&w&col, 13½ min) Cor

The Human Body: Excretory System (b&w&col, 13½ min) Cor

MAJOR CONCEPTS

1. Blood is a peculiar type of connective tissue in that the cells are scattered among the nonliving substances composing the fluid portion.
2. Blood carries water, inorganic substances, digested foods, hormones, and oxygen to the body tissues. It also carries carbon dioxide and nitrogenous wastes, resulting from protein metabolism, for excretion.
3. Hemoglobin, the respiratory pigment, combines with oxygen in the lungs and releases it to the cells. Then it combines with carbon dioxide, which is released in the lungs.
4. Erythrocytes are enucleated cells.
5. Some leucocytes are amoebocytes and move throughout tissue spaces engulfing solid particles and bacteria, when present.
6. Platelets have an important role in the coagulation of blood at the time of an injury.
7. Blood types and the RH factor are

inherited and result from protein substances called antigens.

8. Compatible bloods must be used for transfusions.

9. The heart is a highly efficient pump having two phases in its cycle.

10. Elasticity of the artery walls helps to maintain blood pressure when the ventricles are at rest.

11. All the vital relationships between the blood and the tissues occur in the capillaries and not in arteries and veins.

12. Tissue fluid enters lymphatic vessels and is purified in the lymph glands before returning to the blood.

13. The nephron is the filtering unit of the kidney, and it removes nitrogenous wastes from the blood and maintains water content in the body.

14. The skin, lungs, and liver are also organs of excretion.

ANSWERS TO QUESTIONS FOR REVIEW (Page 599)

1. Plasma contains proteins in the form of fibrinogen, serum albumin, and serum globulin; digested foods in the form of glucose, fatty acids, glycerin, and amino acids; inorganic materials in the form of water, and mineral salts; and nitrogenous wastes such as urea.
2. White corpuscles are produced in the bone marrow and lymph glands. Both red corpuscles and platelets are produced in the red marrow of bones.
3. A high white-cell count usually indicates some kind of infection.
4. Thromboplastin, formed from disintegrating platelets, combines with the enzyme prothrombin and calcium to form thrombin. The thrombin then combines with fibrinogen to form fibrin, which forms a network and traps blood cells, thus forming a scab.
5. Plasma does not require typing. Furthermore, it can be dehydrated and stored, then rehydrated with sterile distilled water. Whole blood is better than plasma because the patient receives red blood corpuscles in addition to increasing the blood volume.

6. A drop of blood entering from the vena cava passes through the right atrium to the right ventricle, then out the pulmonary artery through the lungs, returning to the left atrium through the pulmonary vein. The left atrium pumps it to the left ventricle and out the aorta to the body.
7. When the right ventricle contracts, the blood is being sent to the lungs. When the left ventricle contracts, the blood is being sent to the body.
8. The artery wall, carrying blood from the heart, bulges with each contraction of the heart during systole. A vein, because it has little pressure, does not bulge with heart contractions.
9. The tissue fluid that bathes the cells is called lymph. The lymph glands purify the lymph and return it to the blood. The lymph from the right side of the head and right arm enters the right lymphatic duct, which returns it to the blood by opening into the right subclavian vein. The lymphatics from the rest of the body drain into the thoracic duct, which in turn empties into the left subclavian vein.
10. Lymph contains neither red corpuscles nor platelets. It also lacks certain of the proteins present in whole blood.
11. The kidney capsules receive much of the water and other substances that the blood contains. The content of the blood leaving the kidneys is regulated by reabsorption from the kidney tubules.
12. The glomerular fluid contains not only water and nitrogenous wastes, but foods, salts, and other necessary substances. The urine contains only a small amount of water, some of

the salt, and the nitrogenous wastes.

ANSWERS TO APPLYING PRINCIPLES AND CONCEPTS (Page 599)

1. High blood pressure, kidney disorders, and heart disease may result from hardening of the artery walls. These arterial changes have damaging effects on the general health.
2. With increased circulation in the skin, due to dilation of the blood vessels, the temperature of the body surface would be increased, while the temperature of the vital organs deeper in the body would be decreased.
3. During the first transfusion with positive blood, the Rh-negative person produced antibodies against the factor in his blood. These antibodies caused coagulation of the positive blood when it was added in the second transfusion.
4. Valuable compounds in the body are released into the blood stream and are used to manufacture new red blood corpuscles.
5. During hot weather the flow of perspiration increases greatly, resulting in increased excretion of salt from the blood and tissue fluid. The intake of salt should be increased to keep the salt content of the blood and tissue fluid at a normal level.
6. If water does not enter the glomerulus, due to disease or damage of the arteriole, the water content of the blood and tissues builds up. If it enters the glomerulus and is reabsorbed, the kidney is functioning normally. If it enters the glomerulus and is not reabsorbed in normal quantity in the tubule (as in diabetes insipidus), the urine output increases greatly and the blood and tissues become dehydrated.

Guide to Laboratory Investigations for Chapter 42

INVESTIGATION 42-1

The Blood and Circulation

Scope of the Investigation In this Investigation the student studies the dynamics of blood flow as he observes blood flowing rapidly in arteries and slowly through the

capillaries in the web membrane of a frog's foot. Constriction and dilation of the blood vessels in response to temperature changes are excellent illustrations of homeostatic mechanisms in higher animals (p. 70 of the text).

The student begins his study of human circulation with the preparation of blood smears and microscopic examination of the solid components of blood. Oxygenated and deoxygenated blood is studied. If any students do the C-level activity, they will discover that the structure of red corpuscles is related to their oxygen-carrying capacity.

Approximate time required Part 1 can be completed in 50-60 minutes. Time may be saved by preparing the frog for study before class. Part 2 will require 50-60 minutes. Part 3 will require 30-40 minutes. Part 4 probably should be done over a period of several days. Any student who does this Part should allow at least 40 minutes for the study of blood corpuscles on each animal.

A Part 1 Blood Vessels and Circulation

Suggestions for procedure. Live frogs may be purchased from companies that supply live materials or students may be able to collect their own. Goldfish or tadpoles may be substituted for this study. The adrenalin may be purchased on prescription from the pharmacy.

Immobilize the frog by injecting 10 cc of a 10% urethane solution into the dorsal lymph sac. Hold the frog in your hand, dorsal side up, and watch for a pulsation in the center. This identifies the location of the lymph sac which pulsates at frequent intervals. Lift the skin over the lymph sac and insert a hypodermic syringe through the skin into the lymph sac. The frog should become limp within a short time. An alternate method is to pith the frog, using the technique in Investigation 40-2.

Student observations—answers to questions.

- (a) Skin must be moist so that the frog can respire.
- (b) The capillaries are the smallest vessels; the blood flows more slowly in these vessels and in several directions. Blood flows rapidly in arteries and arterioles and slowly in veins and venules. Blood flow in the arteries and arterioles is toward the foot and away from it in the venules and veins.
- (c) 25-30 microns.
- (d) They allow substances to pass to and from the bloodstream.
- (e) Their walls are formed of a single layer of cells.
- (f) Blood flow slows down; vessels constrict.
- (g) Blood flow speeds up; vessels dilate.
- (h) Blood flow slows down; vessels constrict. Adrenalin produces dilation in skeletal muscles.

A Part 2 Examination of Human Blood

Suggestions for procedure. If time is critical, blood smear slides can be purchased from biological supply houses for this study. However, having students prepare their own provides them with an appreciation of the work done in the field of hematology. Some of them might do the research in Part 4 in which blood smear technique is used.

Students must use aseptic technique in drawing blood from their fingers. A lancet or needle should never be used for more than one student because of the possibility of infection with hepatitis. Caution the student to clean the finger with alcohol-moistened cotton to prevent infection.

Wright's blood stain is a differential stain, staining the nucleus and granules of the white corpuscles so that they are more easily seen.

B Part 3 Effect of O₂ and CO₂ on Blood

Suggestions for procedure. Animal blood may be obtained from a slaughter house or outdated human blood may be obtained from a blood bank. To prevent clotting, add a 1% sodium citrate solution.

As a help in answering the Interpretation, have students review the concept of light absorption in Investigation 6-1.

Student observations—answers to questions.

- (a) Bright red.
- (b) Dark red.
- (c) The blood becomes a brilliant red and frothy.
- (d) Oxygen was released during a chemical reaction between the manganese dioxide and potassium chlorate. The oxygen caused the color change.
- (e) The blood in the test tube should be redder because of the free oxygen that was available.
- (f) Turns it a dark red.
- (g) Oxygenated blood is brighter red than deoxygenated blood.

Interpretation. Blood flowing in the veins is deoxygenated; blood flowing in the arteries except the pulmonary arteries is oxygenated.

The red rays of the visible spectrum are absorbed, and the blue rays are reflected, giving the blood vessels a blue color.

C Part 4 Comparative Study of the Red Blood Corpuscles of Various Vertebrate Animals

Suggestions for procedure. The animals used in this study may be purchased from companies that supply living specimens. The student may collect his own fish, frog, and snake.

The fish, frog, and snake may be sacrificed. This can be done by placing the animal in a container with a wad of cotton saturated with ether. The body cavities may be opened and a small amount of blood drawn from a large blood vessel or from the heart to prepare the blood smear, using the technique described in Part 2 of this Investigation. The bird or mammal need not be sacrificed. Use sterile technique in drawing blood from these animals.

Analysis and conclusions. Flat corpuscles with large nuclei such as those in the cold-blooded frog, fish, and reptile cannot carry much oxygen. The nucleus of the bird's red corpuscle does not occupy as much area as that of other vertebrates. Concave red corpuscles without a nucleus can carry large amounts of oxygen. Warm-blooded animals require large amounts of oxygen to maintain their body temperature.

INVESTIGATION 42-2**Clinical Properties of Blood**

Scope of the Investigation Even after the discovery of blood types by Landsteiner in 1900, people receiving blood transfusions died. In this Investigation the student will understand why when he observes the agglutination of red corpuscles during the blood-typing activity (p. 586 of the text). The presence or absence of the Rh factor discussed on p. 587 of the text is also demonstrated. The student should gain a better understanding of blood clotting (pp. 583 and 586 of the text) as he studies the formation of a clot and factors that influence blood clotting. The laboratory techniques used in

determining the clinical properties of blood are the same as those employed by laboratory technicians hundreds of times a day in laboratories all over the country, wherever a transfusion of blood is required.

Approximate time required The actual typing of blood and determination of Rh type in Part 1 can be completed in 40 minutes if all materials are set up ahead of time and different students are assigned to pricking the finger and mixing the blood on the slide with the sera. Part 2 can be completed in 40-50 minutes.

B Part 1 Blood Typing

Suggestions for procedure. The anti-A, anti-B, and anti-RhD sera can be purchased from clinical supply houses.

The teacher may want to have a signed permission slip from the parent before doing this Part of the Investigation. The student should explain to his family the reason for the study and that aseptic techniques are employed.

To save time in doing this Part, you can train one student to prick the fingers and others to handle the different sera. Agglutination by A and B factors will occur quickly, while Rh agglutination will take 1-3 minutes and will not be as graphic.

Student observations—answers to questions.

- (a) Answers will vary, although it is often close to the average.
- (b) Large numbers of people are required for typing in order to approximate an average. The class may find, however, that they do have a representative distribution of blood types.

Interpretation. The type-AB individual lacks the *a* and *b* agglutinins in his serum. Thus, agglutination does not occur when type-A or type-B blood are transfused. Type-O blood lacks the *A* and *B* agglutinogens on the surface of its red corpuscles, so that agglutination does not occur with *a* and *b* agglutinins.

Rh-negative blood can be safely transfused into an Rh-positive individual because the red corpuscles of the donor lack the Rh factor on their surface and agglutination of the donor's corpuscles does not occur.

B Part 2 Study of Blood Clotting

Suggestions for procedure. The fresh whole blood may be obtained from a slaughter house or outdated human blood may be obtained from a blood bank. To prevent clotting, add a 1% sodium citrate solution.

The student may have to practice making the capillary tubes before he can make one the proper length. Time can be saved by having them prepared before class.

Caution students to use aseptic technique in using the lancet and drawing the blood. The blood drawn into the tube must be left for four minutes. A knowledge of clotting time is important for surgery, because it is frequently necessary to give injections of vitamin K to individuals with slow blood clotting time.

Students should also use aseptic technique in drawing blood from a warm-blooded animal for the study in Section 2. The blood may be drawn from a large vein in the ear of a rabbit or vein in the wing of the chicken.

The thinning of the blood by sodium oxalate and the formation of a clot by the addition of calcium chloride demonstrates the use of blood thinners and diet control for people with high blood pressure and heart diseases.

Student observations—answers to questions.

- (a) Answers will vary; should be from four to eight minutes.
- (b) The low temperature has no effect on the blood.

- (c) The plasma begins to separate from the solid portion of the blood; the blood has begun to clot before it is put on the slide and fibrin threads can be observed.
- (d) The blood becomes thinner and less dense in color.
- (e) The blood begins to form a clot.
- (f) Blood in the shallow dish forms a clot more quickly than the blood in the test tube.
- (g) Air aids in clotting, and more of the blood surface was exposed to the air in the shallow dish.
- (h) Clot is firm in center with a straw-colored fluid around the edge.
- (i) Fibrin.

Interpretation. Low temperatures prevent clotting; high temperatures speed it up. Sodium oxalate thins the blood; calcium chloride causes it to clot. Exposure to air speeds up clotting time.

INVESTIGATION 42-3

The Heart

Scope of the Investigation The student continues his study of circulation in this Investigation by examining the heart, correlating external and internal structure with this organ's function as a pump. A microscopic examination of cardiac muscle reveals the branching nature of the cells and should aid the student in understanding how impulses travel through the heart wall.

Approximate time required Part 1 can be completed in 50-60 minutes. Part 2 should require 15-20 minutes.

A Part 1 Structure of the Heart

Suggestions for procedure. The beef, hog, or sheep heart can be purchased from a slaughter house. If fresh hearts are not available, a model or chart can be used.

The regions of the right and left atria and right and left ventricles can be located by the position of the large blood vessels and slight grooves on the surface of the heart.

The sectioning of the heart to expose the four chambers will be difficult for most students. To save time, the teacher may section several hearts for study or he may teach a student the technique and have him help prepare the hearts for observation. The sectioned hearts can be refrigerated for the next class period if the study in Part 1 is not completed.

Have the student pull on the strands that are attached to the A-V valves and observe how they control the opening and closing. Point out that the contraction and expansion of the papillae have the same effect as pulling.

Student observations—answers to questions.

- (a) Cone shaped.
- (b) Right atrium.
- (c) Answers will vary—about half an inch.
- (d) Answers will vary—about half an inch.
- (e) Thin, nonelastic.
- (f) Left atrium.
- (g) Right ventricle.
- (h) Answers will vary—should be less than the venae cavae.
- (i) Left ventricle.
- (j) Answers will vary—should be greater than the venae cavae.

- (k) Thicker and more elastic.
- (l) They supply the heart cells with oxygen and food and carry away metabolic wastes.
- (m) Right is smaller.
- (n) Answers will vary—about half an inch.
- (o) Myocardium of left ventricle is thicker.
- (p) The left ventricle does more work in forcing the oxygenated blood out of the aorta.
- (q) The septum is a wall entirely separating the two sides of the heart—right and left.
- (r) A glistening membrane.

A Part 2 Study of Cardiac Muscle

Suggestions for procedure. If fresh muscle tissue is not available, a prepared slide of cardiac muscle may be used. Fresh muscle tissue must be stained to make the fibers, striations, and nuclei more distinct. The student should study the slide carefully and note that the branching condition permits a flow of impulses through heart muscle.

Chapter 43

Respiration and Energy Exchange

In introducing the human respiratory system, the difference between respiration, and breathing should be made clear. Also, external respiration, occurring in the lungs, and internal respiration as a cell activity should be distinguished. The necessity of respiratory organs and a circulatory system in supporting the respiratory requirements of the vast number of cells of the human body is an interesting discussion subject. Emphasize the fact that in a complex organism such as man, division of labor and interdependence of cell activity is essential for life.

The mechanics of breathing showing air movements resulting from pressure changes in a closed cavity may be demonstrated by the apparatus shown on p. 604 of MODERN BIOLOGY. The parts of this apparatus, compared with the chest cavity, lungs, and respiratory passages, correct the false idea that lungs draw air in and force it out. Oxygen debt might be explained by an athlete who has experienced it.

A review discussion of cellular respiration (Chapter 7) is helpful at this time. You may want to include the oxygen and carbon-dioxide carrying capacity of the erythrocytes and the mechanism involved in the release of these gases.

Special respiratory problems at high altitudes and in space travel may suggest several reports and current reading assignments which can be used in conjunction with this chapter.

P. 601, left column: The larynx of the male is larger and holds the longer vocal cords needed to produce deeper sounds. When the larynx is removed because of malignancy, people learn to speak by using stomach muscles. This method of talking is taught in special schools.

P. 603, left column: Spareribs bought from a butcher show attachment of muscles important in breathing. Animal lungs may be obtained fresh and then inflated. In some towns, these are available from a butcher or in others from a slaughter house.

P. 610, left column: Demonstrations including lung capacity and a test for CO₂ in exhaled breath are useful. Calculations and tabulations of the breathing rate under different amounts of exertion are interesting.

Reports may be made on diseases of the respiratory system: emphysema, lung cancer, silicosis (an occupational hazard of sand hogs and miners), furriers' lung diseases and others.

Suggested Films

Mechanisms of Breathing, 2nd Edition
(b&w, 11 min) EBF

Respiration (col, 28 min AIBS McGraw-Hill)

The Human Body: Respiratory System
(b&w&col, 13½ min) Cor

MAJOR CONCEPTS

1. Respiration is a life process common to all living things.
2. Respiration in man involves two phases: external and internal.
3. In the lungs, gases are exchanged through the thin capillary walls and the air sacs.
4. Hemoglobin combines with oxygen when the concentration of oxygen is high and releases oxygen when the concentration is low.
5. The affinity of hemoglobin for oxygen decreases with increasing acidity.
6. The movement of carbon dioxide and water in the lungs is the opposite of that of oxygen.
7. The factors that control breathing and breathing rate are both nervous and chemical.
8. During times of muscular exertion, the need for oxygen in the tissues is greater than the body can supply and considerable oxygen debt may be built up.
9. The rate of metabolism may be measured by determining the amount of heat given off from the body surface or by measuring the oxygen consumption.
10. Carbon monoxide is a poison and causes suffocation because hemoglobin has a greater affinity for it than for oxygen.
11. Respiration problems occur at high altitudes.

ANSWERS TO QUESTIONS FOR REVIEW (Page 611)

1. Respiration is an exchange of gases carried on by all living cells. Breathing is a mechanical process involving the lungs and air movements during external respiration.
2. The organs of the respiratory system are: nose, trachea, pharynx, epiglottis, larynx, bronchi, lungs, air sacs, alveoli.
3. Oxygen enters the capillary surrounding the air sac, as the concentration of oxygen in the air sac is higher than that in the capillary. Here it combines with hemoglobin. In the tissues where the concentration of oxygen is lower than in the blood, hemoglobin releases its oxygen. The affinity of hemoglobin for oxygen decreases with increasing acidity. The movement of carbon dioxide and water in the lungs is the opposite of that of oxygen.
4. If the pressure within the chest cavity is reduced to below that of the atmosphere by expanding the chest, air enters the lungs to equalize the pressure. When the ribs spring back and the diaphragm rises, the pressure in the chest rises and air passes through the respiratory passages to the atmosphere.
5. The rate of breathing increases as the amount of carbon dioxide in the blood increases. This increases the oxygen intake in the lungs to supply increased cell respiration needs. Oxygen surplus in the blood has the opposite effect.
6. Artificial respiration is necessary when normal breathing movements have ceased.
7. An oxygen debt is built up when the cells use oxygen faster than the lungs and blood stream can supply it. Thus the blood becomes temporarily low in oxygen content and respiration becomes anaerobic. The debt is paid when the increased need for oxygen ceases and the respiratory organs can replenish the oxygen deficiency in the blood.
8. BMR, or basal metabolic rate, may be determined by the calorimeter test whereby the heat output is measured. Another method, more widely used, measures the amount of oxygen consumed in a definite period.
9. Carbon monoxide combines 250 times more readily with hemoglobin in red corpuscles than does oxygen. Furthermore, it forms a stable compound which is not changed in the tissues. Thus as carbon monoxide

enters the blood, it soon combines with sufficient hemoglobin to destroy the oxygen-combining power of the blood, resulting in death from tissue suffocation.

10. Breathing is difficult on a high mountain because of reduced air pressure and oxygen content. In space, air pressure and oxygen content are so greatly reduced that astronauts must have controlled pressure and an artificial source of oxygen.

ANSWERS TO APPLYING PRINCIPLES AND CONCEPTS (Page 611)

1. During hours of darkness, photosynthesis stops and plants take oxygen from the atmosphere through leaf

stomata. In daylight hours, oxygen released during photosynthesis is used in respiration.

2. If you were to hold your breath for a period of time the carbon dioxide and acid content of your blood would increase and the oxygen content would decrease and respiration would resume. After several deep breaths, breathing stops for a time because the increase in oxygen content of the blood automatically reduces the rate of breathing.
3. Low moisture content of the air increases the rate of evaporation of perspiration from the body surface and increases heat loss. Furthermore, the dry air receives moisture from the lungs more readily and reduces the feeling of stuffiness in humid air.

Chapter 44

Body Controls

This chapter includes the human nervous system and the organs by which the body is made aware of its environment. After becoming familiar with the definitions of the central nervous system and the peripheral and autonomic systems, the student should consider the brain and its regions. Localization of functions in the brain regions and in areas of the cerebrum should be pointed out. A brain model or a chart of the brain will be of great assistance in this teaching. If prepared slides of nerve cells are available, they will add to the interest in the study of the structure of the nervous system. An opaque projector may be used to project photomicrographs for the purpose of focusing attention on certain details. Point out to the students that man is not the first in size, in strength, nor in specialization of other body structures, but that in the degree of specialization of his brain, he has no competition.

Before considering nervous activities, the student should be made familiar with sensory and motor neurons and their relation to the spinal cord and central neurons. The parts of the central nervous system and the path of impulses in a simple reflex may be diagrammed on the chalkboard.

Reactions at higher levels, including conditioned reactions (reflexes) and voluntary acts, may follow the study of simple reflexes.

Following the study of voluntary acts, the autonomic system should be discussed. This system is the key to many psychosomatic illnesses. The I.Q. and its determination and interpretation, tension fatigue, the necessity of sleep, training of memory, formation of habits, and other applications of knowledge of the nervous system and its functions might follow.

The sense organs are gateways to the brain. Through their nerve endings, environmental stimuli initiate the nervous activity that results in awareness of external conditions. This awareness is the basis of learning, understanding, and regulating conscious activity.

Since students usually associate all skin sensations with touch, without realizing that at least five different sensations are involved in the nerve endings of the skin, this is a good place to begin the study of sense organs. A discussion of ways in which these sensations may be localized will provide an interesting introduction to a laboratory on sensations.

Diagrams, charts, and models are helpful when discussing the parts and function of the ear and the eye. The structure of the ear and the conduction of vibrations from the eardrum across the middle ear to the cochlea should be explained thoroughly. This is a physical, almost mechanical, transmission of vibrations. Nervous activity resulting in sound impressions starts in the cochlea. An ear model or a chart of the ear is an excellent teaching aid to accompany this study. Striking a tuning fork and then applying it to the forehead after the sound has faded will provide the student with a better understanding of sound vibration, the conduction of sound through bone, and the stimulation of the sound receptors in the ear.

The eye is of special interest and importance. You may wish to review the photoreceptors of various organisms. The differences in the numbers of rods and cones or the absence of cones altogether is an interesting topic for discussion. Nocturnal and diurnal animals show these differences. Special reports may be desired on these topics as well as on the reflecting pigment layer seen in many nocturnal animals.

P. 613, right column: Cover material on spinal and cerebral meningitis and include the meninges of the brain.

P. 615, Fig. 44-3: A model of the brain will be useful for covering structures and functions. The key to many psychosomatic illnesses lie in the autonomic system. An important breakthrough in the treatment of mental illness is the development of tranquilizers. Another is the willingness to bring the subjects of mental illness and retardation out in the open. Both these could serve as topics for discussion.

P. 623, right column: Hearing difficulties may be due to the aftereffects of childhood illness, injury to the drum, mastoiditis, or immobilization of the ear bones. Research is being done on the causes and treatment of deafness. The Deafness Research Foundation has ear banks where ears are willed to science. When a history of deafness is followed through, and the ears examined after death, information is gained about the value of treatments or any deviation from the normal ear. Healthy ears that are donated are used to train surgeons who operate with the aid of

a microscope and need to practice on real ears.

Striking a tuning fork and then applying it to the forehead after the sound has faded provides a better understanding of sound vibration, the conduction of sound through bone, and the stimulation of sound receptors in the ear. Have a student report on the recently developed ear operation, the stapedectomy.

P. 625, Fig. 44-14: Use a model, if possible, to explain structures and functions of the eye. People may will their eyes to an eye bank for use in cornea transplantation. In the case of both eye and ear donations, the person carries a card with him at all times stating that he wills these organs. This could be valuable in case of an accident.

The Nikon portable fundus camera takes photographs of the back of a person's eyes to help in the diagnosis of eye diseases, cardiovascular diseases, hypertension, diabetes, brain hemorrhages, and other diseases. The photographs are kept as a permanent record and can be referred to in comparative studies during treatment.

P. 625, right column: The use of the laser in surgery should be investigated. What are these and how are they treated: astigmatism, myopia, hyperopia, cataract, and detached retina?

P. 626, Fig. 44-15: Students can perform simple tests like locating the blind spot and testing for color blindness. A student can give a demonstration of the care and use of contact lenses.

P. 627, conclusion: The term *ESP* should become familiar. Students may enjoy duplicating some of the experiments in extrasensory perception.

Suggested Films

Ears: Their Structure and Care (b&w&col, 11 min) Cor

Eyes: Their Structure and Care (b&w&col, 11 min) Cor

Fundamentals of the Nervous System (b&w&col, 17 min) EBF

The Human Body: Nervous System (b&w&col, 13½ min) Cor

The Nervous System in Man (b&w&col, 18 min) Ind

MAJOR CONCEPTS

1. The nervous system receives impressions from the surroundings, stores the information in the brain, originates activity, and carries impulses to all parts of the body.
2. The nervous system coordinates the activity of several million cells into a single functioning unit.
3. Nerves are bundles of nerve cell processes.
4. Neurons are capable of conducting electrochemical impulses.
5. The brain and spinal cord are protected by three membranes.
6. The nerve cell bodies are located in the cortex of the brain.
7. Various motor and sensory areas of the cerebral cortex have been identified.
8. The cerebellum aids the cerebrum in controlling and coordinating muscular activity.
9. A portion of the brain stem, the medulla oblongata, controls the activity of internal organs.
10. The spinal cord transmits impulses to and from the brain and the body.
11. Reflex action can bring about a quick, protective response.
12. The autonomic nervous system is entirely involuntary and automatic.
13. Specialized cells may serve as receptors for specific stimuli.
14. Some receptors, those that are visual and auditory, are contained within specific organs adapted for focusing or amplifying the stimulus.
15. Although the semicircular canals are situated in the middle ear, they function in maintaining balance and have nothing to do with hearing.

ANSWERS TO QUESTIONS FOR REVIEW (Pages 628-629)

1. The general parts of the nervous system include the central nervous system (brain and spinal cord), the peripheral system, and the autonomic system. The central nervous system receives sensory impressions,

initiates and coordinates motor activity, and is the center of memory, intelligence, emotions, and other high-level nervous activities. The peripheral nervous system is an extension of the central nervous system to all parts of the body by means of sensory and motor nerves. The autonomic system regulates activity of the vital organs in an involuntary manner.

2. Peripheral nerves that contain axons are considered to be motor nerves because they are transmitting impulses from the brain and spinal cord to muscles.
3. The motor neuron terminates at the motor end plate. An impulse causes the release of acetylcholine, which causes the contraction of the muscle. After contraction, the nerve ending releases cholinesterase, which neutralizes acetylcholine and causes the muscle fibers to relax.
4. The brain includes the cerebrum, cerebellum, and brain stem including the medulla oblongata, midbrain, and pons. The cerebrum is the center of memory, intelligence, emotion, instinct, sensory impressions, and motor control. The cerebellum coordinates motor impulses from the cerebrum. The medulla oblongata of the brain stem controls impulses to the vital organs.
5. The autonomic nervous system includes both the sympathetic and parasympathetic systems.
6. The five sensations in the skin are touch, pressure, pain, cold, and heat. The receptors are different, but any one may cause the sensation of pain. Some receptors are many-celled; some consist of only one specialized cell; and some are bare nerve endings.
7. Much of the sensation we associate with flavor is actually smell and not taste.
8. The sound waves in the air travel through the auditory canal to the eardrum. These waves cause the eardrum to vibrate, and the vibrations are transmitted and intensified by

the three bones of the middle ear. The fluid of the cochlea allows the vibrations to travel to the nerve endings which transform the vibrations into nerve impulses.

9. A middle ear infection can cause temporary deafness by producing pressure on the eardrum and by causing swelling and discharge which interferes with transmission of vibrations across the bones of the middle ear.
10. The semicircular canals consist of three loop-shaped tubes, each at right angles to the other two. The head movements that stimulate each semicircular canal separately are: the movement of the head forward and backward; the turning of the head; or the raising and lowering of the head by bending and straightening the knees.
11. We see poorly at night because the fovea of the retina, the area in which we see clearly, has no rods. In contrast, the owl can see well at night because of the presence of many rods essential for night vision.
12. You can see objects out of the corner of the eye at night because rods are present in the retina in that area. Since the fovea has no rods, when you focus the image disappears.

ANSWERS TO APPLYING PRINCIPLES AND CONCEPTS (Page 629)

1. Intelligence is a complex relationship between your impressions of past experiences and sensory impressions, your association areas of the cerebral cortex, and your ability to reason and to associate impressions of past experiences with present problems and experiences.
2. The muscle spasms and uncoordinated activities of a chicken with its head cut off result from loss of muscle control by the cerebrum and, especially, the cerebellum.
3. The sympathetic nervous system is often called "the system for fight or flight" because of its control over the heart beat and secretions of glands. When a person is angry or frightened, the glands pour their secretions into the blood stream, and the individual has strength that is not present under normal conditions.
4. Design a pair of spectacles that inverts the image in front of the eye. The eye lenses will then re-invert the image on the retina. If these spectacles were worn continuously, the brain would soon accommodate to this abnormal condition. If the spectacles were then removed, the person would interpret his normal vision as in an inverted image.

Guide to Laboratory Investigations for Chapter 44

INVESTIGATION 44-1

Reflex Actions

Scope of the Investigation Automatic nervous reactions are called reflex actions (p. 617 of the text). In this Investigation the student develops an understanding of a spinal reflex and its significance to human behavior by diagramming the path of a spinal reflex and then studying a knee jerk and pupil reflex as automatic reactions (pp. 618-619).

Approximate time required The entire Investigation can be completed in 50-60 minutes if Parts 2 and 3 are done as a demonstration or by teams of students. If each student does Parts 2 and 3, allow 20 minutes for Part 1 and 40-50 minutes each for Parts 2 and 3.

A Part 1 The Path of a Spinal Reflex

Suggestions for procedure. Have the students study Fig. 44-6 of the text before they label Fig. 44-1-a. Point out that reflex actions are automatic; they are not dependent

on conscious control, past experience, or by training. Reflex actions are protective. Blinking the eye, for example, cleanses it of foreign material and keeps the eyeball moist.

A Part 2 Demonstration of a Spinal Reflex Action

Suggestions for procedure. The teacher may divide the class into teams for this Part or use the demonstration method. Students will need to be properly supervised or this study may degenerate into a play session. Be sure that the student is seated so that his legs hang free.

Student observations—answers to questions.

- (a) A fraction of a second.
- (b) No.
- (c) No.
- (d) No.
- (e) Reflex actions are not consciously controlled.
- (f) 90°.
- (g) The muscles have contracted to their limit when the leg is straight.

A Part 3 Demonstration of the Pupil Reflex

Suggestions for procedure. The teacher may divide the class into teams for this Part to demonstrate the pupil reflex. This study should be carefully supervised, since carelessness could harm the eye.

Student observations—answers to questions.

- (a) It is larger.
- (b) The pupil becomes smaller.
- (c) The pupil opening became larger in the dark to admit more light; it became smaller to shut out the strong light.

INVESTIGATION 44-2

Sensory Receptors

Scope of the Investigation In this Investigation the specific chemical receptors of the tongue are charted and the difference between taste and smell is studied. The demonstration of the uneven distribution of sensory nerves in the skin bears out the discussion on p. 620 of the text as the student actually performs several tests on the skin.

Approximate time required The mapping of the taste areas on the tongue will take 30 minutes. The remaining studies of odors can be completed in 20 minutes if done as a demonstration.

Part 2 will require 20 minutes. The class should be divided into teams for this Part.

A Part 1 The Chemical Senses—Taste and Smell

Suggestions for procedure. The lemon juice, sugar, vanilla extract, salt, and often the Epsom salts can be supplied by the students. Epsom salts, which are not harmful to taste can also be purchased from a pharmacy. Most students have never tasted vanilla extract but are familiar with its sweet odor. They will be surprised to find that it tastes bitter. Explain that this difference between odor and taste is true of several substances, including chloroform, which tastes sweet. Students will also be surprised that they can't distinguish between an apple and an onion.

Student observations—answers to questions.

- (a) No.
- (b) The cube of sugar begins to dissolve and the taste receptors recognize the sugar as being sweet.
- (c) No, sweet is at the tip; salty at tip; sour on sides; and bitter is at the back.
- (d) Magnesium sulfate tastes sweet at the tip of the tongue and bitter at the back.
- (e) Sweet.
- (f) Bitter.
- (g) They should not recognize the apple.
- (h) They should not recognize the onion.
- (i) An apple and an onion are distinguished by their odors, not by their taste.

A Part 2 The Sensations of the Skin

Suggestions for procedure. Aristotle's experiment using the crossed fingers demonstrates our dependence on previous experience for interpretation of touch stimuli. The subject recognizes the single point of a pencil as two because from experience he has learned that when those two areas of skin are stimulated they are being touched by two objects. When the pencil is placed between two uncrossed fingers, he will recognize only one object. Apparently brain cells receiving stimuli from opposing sides of the fingers are closer together than those from the same side.

Student observations—answers to questions.

- (a) The student should recognize the pencil as being two pencils.
- (b) Probably three to four inches.
- (c) Probably between two and three inches.
- (d) Probably one to one and a half inches.
- (e) Probably one-fourth to one-sixteenth of an inch.
- (f) Forearm.
- (g) Inner surface of the index finger.

INVESTIGATION 44-3**Hearing and Equilibrium**

Scope of the Investigation The human ear is studied by examining a model, chart, or Fig. 44-3-a and relating structure to function (pp. 622-623 of the text). The demonstration of loss of equilibrium bears out the discussion of the relation of the movement of fluid in the semicircular canals to the maintenance of equilibrium on p. 624 of the text. The student also demonstrates that head and eye movements are reflex adjustments in a direction opposite to rotation.

Approximate time required Part 1 will require 40-50 minutes. The equilibrium studies in Part 2 should be demonstrations or assigned to teams and will require 40-50 minutes.

A Part 1 Structure of the Ear

Suggestions for procedure. The teacher may handle this Part as a demonstration, having the student point to and name each part of the ear, giving its function. Then he can label the parts of the ear in Fig. 44-3-a.

Student observations—answers to questions.

- (a) Directs sound waves into the external auditory canal.
- (b) By Eustachian tubes.

- (c) So that air pressure is equalized on either side of the tympanic membrane.
- (d) Tympanic membrane (eardrum).
- (e) Hammer, anvil, and stirrup.
- (f) It contains the organ of hearing.
- (g) Maintain equilibrium.
- (h) Hair cells.

A Part 2 Equilibrium Reactions in Man

Suggestions for procedure. Let the subject volunteer for this activity, since some students get nauseated easily.

The inability of the subject to orient himself in the last two demonstrations is due to the movement of the fluid in the semicircular canals as he was rotated in the chair.

Student observations—answers to questions.

- (a) The eyes and head are moved in the direction opposite to the rotation.
- (b) The student probably reports that he saw parts of the room as he turned toward them. He does not report any movement of the head other than that it turned as the body did.
- (c) The student was actually looking back as the chair rotated.
- (d) No.
- (e) Individuals who are right-handed will point to the left of the examiner's finger; those who are left-handed will point to the right of the examiner's finger.
- (f) Without seeing the examiner's finger, the student has no basis for where to point. This result also bears out the fact that motor response is controlled more on one side of the cerebral hemisphere than on another.
- (g) No.
- (h) Individuals who are right-handed will probably point to the right of the examiner's finger; those who are left-handed will probably point to the left of the examiner's finger.
- (i) The results are opposite to those in the previous experiment.
- (j) Backward toward the left.
- (k) To the left if right-handed; to the right if left-handed.

INVESTIGATION 44-4

The Eye and Vision

Scope of the Investigation This Investigation begins with a study of a model of the mammalian eye, a chart, or a fresh cow or sheep eye, and relates structure to function (pp. 624-626 of the text). A careful dissection of a cow or sheep eye follows. The student determines his near point of vision, demonstrates the blind spot in his eye, and gains a graphic understanding of positive and negative afterimages.

Approximate time required Part 1, which may be omitted if Part 2 is done, will require 20-30 minutes. Part 2 will probably require 80 minutes. Part 3 will take 10 minutes and Part 4 probably 35-40 minutes.

A Part 1 Structure of the Eye

Suggestions for procedure. This Part may be omitted if the dissection is done, with the student answering the questions after he has completed Part 2.

Student observations—answers to questions.

- (a) Turns the eye downward.
- (b) Rotates the eye outward.
- (c) Rotates the eye inward.
- (d) Superior oblique: rotates the eyeball downward and outward; inferior oblique rotates it upward and outward toward the temple.
- (e) Protection.
- (f) Prevents light reflection in the eye.
- (g) Contains the photoreceptors that extend to the optic nerve.
- (h) Transmits light rays to the optic center of the brain.
- (i) Forms front part of the eye, protection.
- (j) Regulates the size of the pupil opening.
- (k) Supports the lens; contraction results in the change in shape of the lens.
- (l) Admit light.
- (m) The focusing of light rays on the retina.
- (n) Keeps eyeball moist and prevent its collapse.
- (o) Keeps eyeball firm; maintain shape of cornea.

A Part 2 Dissection of the Eye

Suggestions for procedure. Fresh eyes can be obtained from a slaughter house. Two students should be assigned to dissect an eye.

In cutting out the optic nerve, have one student do the dissecting while another plugs the hole with the cover glass. In looking through the eye, the student will have to move the eye in several directions before he can see an image, which will probably be blurred. The removal of the cornea is similar to the technique a surgeon uses in making a corneal transplant.

Student observations—answers to questions.

- (a) Answers will vary.
- (b) At the back of the eye.
- (c) Muscle fibers penetrate the sclera.
- (d) Spherical.
- (e) Transparent and lacks tough tissue of sclera.
- (f) Right side up.
- (g) The lens changes shape.
- (h) It does not magnify.
- (i) Convex.
- (j) It is elastic.

A Part 3 Demonstration of Visual Accommodation

Suggestions for procedure. All students in the class can do this activity. If they wear glasses, have them check their vision with and without the glasses. They will be very interested in the difference between their actual vision and corrected vision. The student can hold the ruler extending from the forehead at a point above the nose and have a second student read the distance to which he has moved the pin. The eyes may differ in their near point of vision.

Student observations—answers to questions.

- (a) Answers will vary.
- (b) Answers will vary.

A Part 4 Locating the Blind Spot

Suggestions for procedure. The blind spot is the area in which there are no receptors.

Each student should perform this activity. A second student should measure the distance while the subject is holding the book in the proper place.

Student observations—answers to questions.

- (a) Light rays fall on the blind spot.
- (b) No.
- (c) The blind spot is not located in the same spot for all individuals.

A Part 5 Positive and Negative Afterimages

Suggestions for procedure. The students may go into a darkened stock room if the classroom cannot be darkened sufficiently for this demonstration. The light need remain on for only a second. Several small pieces of papers of different colors can be used for the study of negative afterimages.

Student observations—answers to questions.

- (a) Positive.
- (b) Three or more seconds.
- (c) Afterimage is in complimentary color of the lights; green if light was red, blue if yellow, and red if green.
- (d) Negative.
- (e) Yes.
- (f) The cones become fatigued and the afterimage appears in the complimentary color.
- (g) A green spot appeared on the white paper if red was used.
- (h) Negative.
- (i) A green spot appeared.
- (j) Should see the complimentary color.
- (k) Negative.

Chapter 45

Alcohol, Narcotics, and Tobacco

The use of alcoholic beverages has produced such widespread problems in our society today that some consideration should be given to this topic in the biology course. The physiological effects of alcohol should be explained. Alcoholism should be considered an emotional disorder, related to environmental problems more deeply rooted than alcohol itself.

Narcotic drugs present an even more insidious problem than alcoholic beverages. Since the use of narcotics often begins in adolescence and young adult life, the danger of these drugs and the inevitability of drug addiction among users should be stressed.

Tobacco must be considered in a light quite different from alcohol and narcotics. Otherwise, students who smoke or see their parents and friends smoke may get the

false impression that alcohol and narcotics are no more harmful or dangerous. The best approach to the consideration of smoking is a common-sense approach which emphasizes its uselessness and possible physiological effects. The Public Health report of 1964 presents much data relating smoking to a higher percentage of deaths from numerous causes.

P. 630, right column: The third paragraph explains why alcoholics are sometimes found dead of exposure. Report on the work of Alcoholics Anonymous.

P. 634, left column: Find out how other countries treat the narcotics problem. Discuss Great Britain which treats the addict as a medical problem and the United States, which treats it as a criminal problem. Investigate accounts of attempts to make a different approach in this country.

In the days when opium could be obtained for a few pennies in an apothecary shop, Poe and DeQuincy were among the addicts.

P. 636, right column: Have students look up the British report on smoking as well as the United States report. What effect has it had on tobacco consumption? What pressures are exerted to maintain the status quo in consumption? What can be done to discourage young people from taking up the habit?

Suggested Films

Alcohol and The Human Body (b&w, 14 min) EBF

Tobacco and The Human Body (b&w, 15 min) EBF

MAJOR CONCEPTS

1. Problems resulting from alcohol and narcotics are more acute today because automobiles, firearms, and other mechanical devices become implements of destruction in the hands of an intoxicated or drug-addicted person.
2. Alcohol does not have to be chemically changed before it is absorbed in the stomach.
3. A large amount of heat and some water are produced from the oxidation of alcohol, but their dissipation dehydrates the tissues.
4. The liver and stomach are harmed by alcohol.
5. Alcohol is a depressant and acts as an anesthetic on the nervous system.
6. Acute alcoholism can lead to terrifying hallucinations.
7. Heavy drinking shortens life considerably.
8. The alcoholic's family and all society pay a price.
9. Continued use of narcotic drugs results in both mental and physical addiction.
10. People may become addicted to narcotics in several ways.
11. Smoking causes tissue damage in the lungs.
12. Circulatory diseases, lung cancer, chronic bronchitis, emphysema, cancer of the tongue, larynx, and esophagus, and peptic ulcer have been correlated with smoking.

ANSWERS TO QUESTIONS FOR REVIEW (Page 638)

1. Alcohol is not a food because it does not yield material for use in growth and repair of tissues, interferes with many cellular processes, and does not yield energy in relation to the body's needs. Energy is liberated from alcohol as a large amount of useless heat.
2. It is absorbed from the stomach rapidly and may reach the blood in two minutes. Absorption of alcohol continues in the small intestine. The blood carries it to the tissues, where oxidation in the cells occurs rapidly. Heat from this oxidation is carried to the skin. Some of the alcohol is excreted as vapor from the lungs and skin. Much of it reaches the kidneys in solution in water.
3. The liver is especially affected by alcohol as it must detoxify it. Alcohol causes cirrhosis of the liver and can cause damage to the brain.
4. The idea that alcohol is a body stimulant is purely psychological. Actually, it is a depressant.
5. Alcohol shows its effects in the brain cortex, causing loss of judgment, will power, and self-control.
6. An alcoholic drink slows sensory and motor reaction time and impairs judgment and emotional control. These are the hazards in driving an automobile.
7. Narcotic drugs, according to classification by the federal government, include opium, morphine, heroin, codeine, cocaine, and marijuana.
8. Anyone who starts using narcotic drugs regularly will become addicted. The emotionally disturbed and underprivileged are particularly susceptible.
9. There were 70 percent more deaths from all causes among smokers than among nonsmokers. The greater number of deaths from certain diseases among smokers was particularly marked. There were 1000 percent more deaths from lung cancer and 500 percent more from chronic bronchitis and emphysema.

10. Smoking is an expensive habit and gets more so every year. It also stains the teeth and fingers. It is messy and annoying to other people who do not smoke. It causes throat irritation, nervousness, and stomach discomfort due to increased gastric activity.

ANSWERS TO APPLYING PRINCIPLES AND CONCEPTS (Page 638)

1. Food in the stomach reduces the rate of absorption of alcohol.
2. Large amounts of heat, released from the tissues and received by the blood, reach the skin in an increased flow of blood in the skin capillaries. The presence of this excess flow of blood in the skin causes a flush and a false

- feeling of body warmth, due to stimulation of heat receptor nerves in the skin.
3. Vital statistics indicate that excessive use of alcohol and heavy smoking shorten life. Thus these two practices are related directly to the risk in insuring a client.
4. Drug addiction requires that the user deal illegally with organized crime in order to get his supply. Furthermore, drugs may cost as much as forty dollars a day, and most users have to steal to obtain this much money. Drug addicts and alcoholics show character weakness by trying to cover up their problems rather than solving them.
5. Inhaling smoke carries it into the bronchi and lungs.

Chapter 46

Body Regulators

The study of endocrine glands and their hormone secretions is a fascinating part of human biology. The concept of chemical secretions regulating behavior and to a great extent determining much of the personality is an entirely new idea to most students. The first approach to the study of the endocrine system is an understanding of what hormones are and what they do. Distinction should be made between ductless glands and other glands. The role of the circulatory system in delivering hormones to body tissues far removed from the glands should be explained.

According to the concept of dynamic balance, the hormones of one gland influence the functioning of other glands. Thus glands remain in balance with the level of activity of other glands of the endocrine system. This concept largely replaces the idea that the pituitary gland is the "master gland." It is true that hormone secretions of the anterior lobe of the pituitary gland do influence the activity of other glands. But conversely, other glands also influence the activity of the pituitary gland. The concept of feedback control is a good topic for discussion as well as reports on current research.

As you teach each gland and its hormone secretion, point out the result of hypo- and hyperactivity. Glandular diseases are fascinating topics for class discussions. The correction of these conditions by administration of hormones or by surgery is equally dramatic. A map of the goiter area of the United States is valuable. This map should be accompanied with a report on hypothyroidism and goiter resulting from iodine deficiency. Other reports might be given on hyperthyroidism, cretinism, giantism, acromegaly, diabetes mellitus, and Addison's disease.

P. 639, right column: Pictures of glandular disturbances kept on file are a useful teaching aid.

P. 640, left column: Surgery is used to cut down the blood supply to the gland or remove it. When it has been removed, the person must take thyroid extract for the rest of his life. It has the advantage of being taken orally.

P. 641, left column: If there is too little parathormone, violent muscle contractions called tetany result. Cases of odd growth are recorded in medical history such as a young child giving birth to a child and a seven-year-old dying of old age.

P. 643, Fig. 46-5: Refer to the adrenals in the frog. From the butcher get sweetbreads (pancreas) and tell about their preparation in cooking.

P. 643, left column: The adrenals produce complex substances which are used to treat other diseases. The use of steroids in connection with trichinosis has already been mentioned.

P. 644, left column: Distinguish between diabetic shock (too much sugar, not enough insulin) and insulin shock (too much insulin, not enough sugar). Diabetics usually carry a card with them in case either of these conditions should occur. Otherwise they are often mistaken for drunks in an emergency.

P. 644, right column: Castration in animals results in the gelding, capon, ox, and eunuch. Man has deliberately done this over the centuries with different purposes in mind.

Suggested Films

Hormones (col, 28 min) AIBS McGraw-Hill

Principles of Endocrine Activity (b&w&col, 16 min) Ind

MAJOR CONCEPTS

1. Ductless glands secrete hormones which are transported by the blood stream to a distant part of the body where they regulate an activity.
2. The thyroid hormone regulates the rate of metabolism.
3. Parathormone controls the use of calcium in the body.
4. Although the pituitary gland influences the activity of all the other endocrine glands, it is also affected by the others.
5. Common disorders of the pituitary result in growth disturbances.
6. The adrenal cortex produce hormones which control certain phases of metabolism as well as salt and water balance in the body.
7. The adrenal medulla produces the emergency hormone.
8. The pancreas produces insulin, which is essential for the liver to store glycogen and for the oxidation of sugar.
9. The gonads produce hormones that

control the development of the secondary sex characteristics.

10. Although the endocrine glands control the various body activities, they are, in turn, influenced by feedback and by the nervous system.

ANSWERS TO QUESTIONS FOR REVIEW (Page 647)

1. The blood delivers the substances required by endocrine glands in producing hormones and delivers the hormones to the body tissues.
2. Thyroid hormone regulates the rate of oxidation as well as other metabolic functions of cells.
3. Hypothyroidism lowers the rate of metabolism. During infancy and early childhood, this may result in cretinism. Later in life, it may cause sluggishness and a tendency to become overweight. Hyperthyroidism may cause a rise in body temperature, increase in blood pressure and heart action, sweating, extreme nervousness, and irritability.
4. The pituitary gland produces the somatotrophic hormone, which regulates the growth of the skeleton and other connective tissues. Underactivity may result in a pituitary dwarf, or midget. Overactivity may produce a giant. The thyroid gland influences growth through its effect on cell metabolism. A thyroid dwarf is a cretin.
5. The gonadotropic hormone of the anterior lobe of the pituitary gland influences the development and activity of the reproductive organs.
6. The thyroid dwarf and pituitary dwarf are similar only in that both are small. The thyroid dwarf has a stunted body, a bloated face, large lips and, in many cases, a protruding tongue. He is usually mentally retarded. The pituitary dwarf is small but proportioned normally and is of normal intelligence.
7. ACTH is a secretion of the anterior lobe of the pituitary gland. It stimulates the adrenal cortex.
8. At puberty, the reproductive organs mature and begin the secretion of estrogen or testosterone. These result

in the appearance of secondary sexual characteristics and sweeping emotional changes. Sexual maturity is linked closely with the action of the gonadotropic hormone of the anterior lobe of the pituitary gland.

9. A diabetic has a deficiency in insulin, produced in the islet cells of the pancreas. Because of insulin deficiency, a diabetic cannot normally store sugar in the liver, nor can his cells utilize blood sugar. Thus, sugar appears in the blood and is excreted in the urine. Recent research indicates an enzyme may control the action of insulin.

ANSWERS TO APPLYING PRINCIPLES AND CONCEPTS (Page 647)

1. The thyroid gland, because of its influence on the metabolism of cells

through thyroid hormone, may influence intelligence.

2. Emotional tension and excitement of a basketball player or other athlete before a game increases adrenal function. Increase in epinephrine in the blood increases the rate of heartbeat as well as other functions.
3. Both the endocrine and nervous systems are control systems.
4. The female hormone estrogen, injected into the blood stream of a male rat, will produce a mothering instinct, just as its secretion normally does in the female.
5. In feedback, the accumulation of a substance in the blood automatically cuts down its production by the endocrine gland. Conversely, a shortage of the hormone triggers its increased production by the gland. In this way a state of balance is achieved.

Chapter 47

Reproduction and Development

A review of the significance of sexual reproduction as a genetic combination of differing traits compared to asexual reproduction will serve as a valuable introduction. A review of gametogenesis (Chapter 8) will provide a background for this chapter. The anatomy of the reproductive organs should be related to the function. Explanation of the ovarian cycle re-emphasizes the nature of the endocrine glands and feedback in controlling an organ.

The development of a zygote and the cell differentiation proceeds in an orderly fashion. The development of the germ layers may be made clear to the students by using a series of models. Formation of the gastrula can be shown by using a flexible, hollow rubber ball and pushing in at one point. If you wish to cover embryology in more detail, reports can be given on the various phases. Colored diagrams will clarify the progressive development of the germ layers.

The nourishment of the embryo and fetus of the placental organism may be discussed and compared to the marsupial and the egg-laying animals. The birth of the

baby culminates the chapter. Many schools have museums in which specimens of placental animals in the uterus are available. These are helpful in showing the relationship of the young to the mother. Changes in fetal circulation and the beginning of respiration in the offspring accompany the birth of the baby and these should be discussed with the class. A diagram showing the ductus arteriosus connecting the pulmonary artery with the aorta may be put on the chalkboard to clarify the location and function of this vessel.

Student questions are best answered anonymously. Have the questions written on a piece of unsigned paper and collect them. Answer the questions even if the language floors you and you have to reword them!

P. 648, left column: Review the Mongolian idiot which has an extra chromosome, making 47.

P. 649, Fig. 47-1: Use the diagram to show the passage of semen and its constituents. A prepared slide of human sperm can be set up as a demonstration. Leeuwenhoek saw human sperm. Discuss outmoded theories of reproduction.

P. 650, Fig. 47-3: Follow the diagram to show passage of an egg. Explain ectopic pregnancy. Use an animated film dealing with human reproduction.

P. 652, Fig. 47-5: Have an open-book lesson.

P. 653, Fig. 47-6: Use models or draw with colored chalk on the board to show development of the three primary layers of the embryo. Refer again to p. 186, Fig. 13-4 and "ontogeny recapitulates phylogeny."

P. 654, left column: The commonly used term for the amnion is the "bag of waters." When a child born with a caul (amnion) over its head, it is considered good luck. Other superstitions having to do with reproduction are known by students. One is the superstition that if the mother listens to good music while she is carrying the child, the child will be born musically talented.

Suggested Films

Fertilization (col, 28 min) AIBS McGraw-Hill

The Human Body: Reproductive System (b&w&col, 13½ min) Cor

The Physiology of Reproduction (b&w, 29 min) Ind

MAJOR CONCEPTS

1. The mechanism of the separation of chromosome pairs assures variation in the genetic composition of the gametes.
2. Formation of the zygote combines genes and produces offspring that resemble the species but vary from each parent.
3. The testes of the male produce the haploid sperm.
4. The ovaries of the female produce the haploid ova.
5. The development of the ovum and of the uterus are coordinated by hormones.
6. Fertilization occurs in the Fallopian tube and when the zygote reaches the uterus, three to five days later, it implants itself in the uterine wall.
7. Repeated divisions occur in a regular and orderly fashion.
8. Gastrulation forms the endoderm and ectoderm.
9. The mesoderm is formed when endodermal cells grow into and fill the blastocoel.

10. Cellular differentiation continues, and the structures of the fetus are formed from the three primary germ layers.

11. The fetus is nourished through the umbilical cord attached to the placenta.

12. At the time of birth the lungs fill with air, and the ductus arteriosus closes so that blood circulates through the lungs.

ANSWERS TO QUESTIONS FOR REVIEW (Page 657)

1. Sexual reproduction allows for genetic recombination and thus variation of individuals.
2. Sperm are produced in the testes and they pass through the seminiferous tubules, epididymis, vas deferens, seminal vesicle, past the prostate and Cowper's gland, and out the urethra.
3. There are about 130 million sperm to every ovum. The semen, containing the sperm, alters the chemical reaction and allows the sperm to travel to the ovum where one sperm will unite with the egg.
4. The ovum leaves the ovary and is swept into the Fallopian tubes by cilia. The ovum travels into the uterus and if fertilization does not occur, it is discharged through the vagina.
5. The development of the ovum and of the uterus are coordinated by hormones. The ovary forms a follicle where the ovum is developing. This cycle is controlled by FSH, produced in the anterior lobe of the pituitary. As the egg matures, the follicle produces estrogen and the follicle becomes the corpus luteum. This is controlled by another hormone, LH, also produced by the pituitary gland. The corpus luteum in turn produces progesterone, which maintains growth of the lining in the uterus. If the ovum is not fertilized, the corpus luteum degenerates and progesterone is not produced and the lining of the uterus is discharged.

6. a. Menstruation is the discharging of the uterine lining. b. The follicle stage occurs from the end of menstruation to the release of the ovum. c. Ovulation is the release of a mature ovum from the ovary. d. The corpus luteum stage lasts from ovulation to menstruation.
7. The zygote divides into two cells soon after fertilization. Then, by successive divisions, it soon forms a sphere of cells and then a hollow ball. An indentation in one area marks the beginning of the gastrula and the formation of three germ layers. Differentiation begins to become more obvious as the embryo becomes a fetus.
8. The chorion, which attaches the embryo to the uterine wall; the amnion, which forms a fluid-filled cavity and protects the developing embryo from injury and keeps it moist; the yolk sac, which is small and insignificant in the human; the allantois, which is present in man for only a short time, but serves in respiration in birds and reptiles.
9. See the table on page 655.
10. The umbilical cord is formed by the lengthening of the yolk sac and the allantois. It contains two umbilical arteries and one umbilical vein.
11. After birth, the ductus arteriosus closes off so that the blood must pass through the pulmonary arteries to the lungs.

ANSWERS TO APPLYING PRINCIPLES AND CONCEPTS (Page 657)

1. The sperm is shaped like a tadpole and has a tail which propels it through the fluid. It contains the haploid set of chromosomes, as does the egg. The egg is larger, has some nutrients, and is not motile. The function of the sperm is to travel to the egg and deliver its set of chromosomes.
2. Fertilization must occur in the Fallopian tube prior to the movement of the ovum into the uterus in order that the chorionic membrane has time to form the villi which will adhere to the uterine wall.
3. Since the pituitary gland produces FSH and FL, which influence the development of the ovary, anything altering the normal function of the pituitary would alter the course of events in the ovary.
4. If an egg is fertilized, the corpus luteum continues to produce progesterone, which functions to maintain the growth of the uterine lining.
5. During fetal life, the ductus arteriosus functions to carry blood from the pulmonary artery to the aorta, thus short-circuiting the lungs, which are not functioning. Shortly before or after birth, this vessel closes off and the blood passes through the pulmonary artery to the lungs. Failure of the vessel to close is one cause of a blue baby. A mixing of oxygenated and deoxygenated blood occurs.

Suggested References for the Teacher—Unit VII

Books

- Alexander, P. *Atomic Radiation and Life*. Penguin Books, Baltimore, Md., 1957
- Ames, G. *The First People of the World*. Harper and Row, New York, 1958
- Asimov, Isaac, *Chemicals of Life: Enzymes, Vitamins, and Hormones*. Abelard-Schumann, Ltd., New York, 1954
- Auerbach, Charlotte. *Genetics in the Atomic Age*. Oxford University Press, Fair Lawn, N.J., 1956

- Bates, M. *Man in Nature*. Prentice-Hall, Englewood Cliffs, N.J., 1961
- Bates, M. *The Prevalence of People*. Charles Scribner's Sons, New York, 1956
- Best, Charles A. and Taylor, Norman B. *The Living Body*. 4th ed. Holt, Rinehart and Winston, New York, 1958
- Boyd-Orr, John. *The Wonderful World of Food, the Substance of Life*. Doubleday and Co., New York, 1958
- Cosgrove, M. *Wonders of Your Senses*. Dodd, Mead, and Co., New York, 1958

D'Amour, F. E. *Basic Physiology*. University of Chicago Press, Chicago, 1961

Dobzhansky, T. *Mankind Evolving: The Evolution of the Human Species*. Yale University Press, New Haven, Conn., 1962

Fenton, Carroll L. *The Fossil Book: A Record of Prehistoric Life*. Doubleday and Co., New York, 1958

Glemser, B. *All About the Human Body*. Random House, New York, 1958

Harrison, R. J. *Man, The Peculiar Animal*. Penguin Books, Baltimore, 1958

Haskins, C. P. *Of Societies and Men*. W. W. Norton Co., New York, 1951

Haydock, Kay S. *Your Allergy and You*. Holt, Rinehart and Winston, New York, 1958

Hogarth, P., and Salomon, J. J. *Prehistory*. Dell Publishing Co., New York, 1962

Hunter, I. *Memory: Facts and Fallacies*. Penguin Books, Baltimore, Md., 1958

Ley, Willy, *Rockets, Missiles, and Space Travel*. The Viking Press, New York, 1957

Mathison, R. *The Eternal Search: The Story of Man and His Drugs*. G. P. Putnam's Sons, New York, 1958

Milne, L., and Milne, M. *The Senses of Animals and Men*. Atheneum Publishers, New York, 1962

Montagu, A. *Man: His First Million Years*. New American Library of World Literature, New York, 1958

Morrison, Cornett, and Tether. *Human Physiology*. Holt, Rinehart and Winston, New York, 1959

Pierce, John R. and David, Edward E. Jr. *Man's World of Sound*. Doubleday and Co., New York, 1958

Articles

Amoore, John E., *et al.* "The Stereochemical Theory of Odor." *Scientific American*, February, 1964

Barron, Frank *et al.* "The Hallucinogenic Drugs." *Scientific American*, April, 1964

Botelho, Stella Y. "Tears and the Lacrimal Gland." *Scientific American*, October, 1964

Brady, Joseph V. "Ulcers in 'Executive' Monkeys." *Scientific American* October, 1958

Brazier, Mary A. B. "The Analysis of Brain Waves." *Scientific American*, June, 1962

Coe, Michael D. "The Chinampas of Mexico." *Scientific American*, July, 1964

Crombie, A. C. "Early Concepts of the Senses and the Mind." *Scientific American*, May, 1964

Csapo, A. "Progesterone." *Scientific American*, April, 1958

Daniel, G. E. "The Idea of Man's Antiquity." *Scientific American*, November, 1959

Dole, Vincent, P. "Body Fat." *Scientific American*, December, 1959

Fender, Derek H. "Control Mechanisms of the Eye." *Scientific American*, July, 1964

Fenn, Wallace O. "The Mechanism of Breathing." *Scientific American*, January, 1960

Fisher, Alan E. "Chemical Stimulation of the Brain." *Scientific American*, June, 1964

Freireich, Emil J. and Frei, Emil III. "Leukemia." *Scientific American*, May, 1964

French, J. D. "The Reticular Formation." *Scientific American*, May, 1957

Howells, William W. "The Distribution of Man." *Scientific American*, September, 1960

UNIT EIGHT

ECOLOGICAL RELATIONSHIPS

Although ecology has been used as an introduction to biology, the relationships of plants and animals to one another and to their environment actually weaves through the entire course. However, after a background knowledge of the diversity of living forms and the requirements for life, many ecological concepts can be discussed in depth and with more meaning. This unit treats the organisms as living societies. In various communities, organisms interact with conditions of the environment and with one another in a dynamic system.

Our understanding of the complex relationships that exist among different organisms and the environment will be reflected in the heritage we will leave for the future generations. An understanding of reasons for game laws, controlled timber cutting, crop rotation, terracing and water control, will help us to become better citizens. We still have much to learn about conservation because the results of poor practices often appear many years later.

OUTCOMES

The study of this unit should result in:

1. Understanding of the relationships of living things to one another and to their surroundings.
2. Knowledge of the water, carbon-oxygen, and nitrogen cycles as they affect and are affected by organisms.
3. Understanding of the levels of organization in the ecosystem.
4. Knowledge of how ideal conditions for diverse organisms are provided by many different kinds of habitats.
5. Understanding of how certain limiting factors may influence organisms.
6. Knowledge of various nutritional relationships among living organisms.
7. Understanding of how periodic changes in the environment influence the behavior of organisms.
8. Understanding of factors involved in the distribution of organisms on the earth.
9. Knowledge of how succession studies may be used to predict future changes as well as to visualize what has happened in the past.
10. Awareness of conservation problems and their causes.
11. Awareness of the tragic effects of soil loss on plant and animal populations.
12. Familiarity with the forest regions of North America and forest conservation measures.
13. Knowledge of the uses of forests and forest products.
14. Understanding of causes of forest destruction.
15. Knowledge of the relation of water conservation problems to the fish conservation program.
16. Awareness of the critical problems involved in conserving many birds and mammals which are nearing extinction.
17. Knowledge of wildlife conservation methods.
18. Desire to take an active part in the conservation programs.

Chapter 48

Introduction to Ecology

The ecosystem is introduced as a unit of the biosphere and as a unit in which materials cycle. The students should be familiar with the levels of organization within the biosphere, and they should be able to give examples of the three kinds of relationships occurring in an ecosystem. These basic understandings are more easily understood when the teacher uses biotic communities and populations of organisms with which the students are familiar.

Class discussions can bring out the important processes involved in the water

cycle, nitrogen cycle, and carbon-oxygen cycle. Logical thinking can be guided by the teacher if a diagram of each cycle is put on the chalkboard as the students make suggestions to develop the complete cycle. Once the cycles have been completed, it is suggested that the teacher choose an ecosystem familiar to the students and near the school. From this familiar "living room," the students can search for examples of the effects of various populations on different phases of the cycles. The alfalfa field, for example, adds moisture to the air in the

process of transpiration; the bacteria living in the roots fix nitrogen by removing it from the air; the overall process of the plants in the carbon-oxygen cycle is to add oxygen to the atmosphere and to remove carbon dioxide. The complexity of the cycles will become evident when the effect of each cycle on various populations is considered next.

Although biologists often speak of the "balance of nature," specific populations may show considerable annual variations. The factors controlling the population density of any particular organism should be discussed with examples familiar to the students.

P. 664, right column: For further information on the water cycle and clouds consult books on meteorology. Of special interest to students are lightning, storms, how electricity is built up at the surface of the earth by falling rain, and how to compute the distance of a storm.

P. 666, Fig. 48-4: Review the chemistry of photosynthesis and respiration. (Chapters 6 and 7).

P. 668, left column: Bring in samples of legumes: seeds, fresh or dried plants, and roots (to show nodules).

P. 670, Fig. 48-7: If possible, show owl wing feathers to illustrate the special adaptation for silent flight.

Suggested Films

Population Ecology (col, 28 min) AIBS McGraw-Hill

The Community (b&w&col, 11 min) EBF

What is Ecology? (b&w&col, 11 min) EBF

MAJOR CONCEPTS

1. No organism is independent of its environment.
2. The biosphere is the area in which life on our planet is possible.
3. Ecosystems are units of the biosphere in which living and nonliving things interact and in which materials are used over and over again.
4. Populations vary in numbers of individuals from season to season and year to year.
5. Population density studies provide valuable information.
6. Different levels of organization occur in the ecosystem.
7. In an ecosystem interactions occur in the biotic community, between the biotic community, and the physical environment, and among the physical factors.
8. Water, carbon dioxide, oxygen, and nitrogen cycle in the ecosystem.
9. The relationships between organisms are not static.

ANSWERS TO QUESTIONS FOR REVIEW (Page 671)

1. The biosphere is the area in which life on our planet is possible.
2. By counting the individual organisms of any species in a definite area that we consider representative, we can make an estimate regarding the density of the species in a larger area.
3. Populations vary from year to year, but some factors determining the population of an organism at any time are the rates at which individuals are dying, being produced, or moving into or out of the area.
4. No, the list of biological organization pertaining to the sponge would only go as far as the cellular level.
5. There are interactions between the ecosystem and the physical environment as well as the biotic community. However, there are also interactions between the physical environment and the biotic community.
6. Interactions between the biotic community and the physical environment include the ways in which organisms are affected by sunlight, soil, and temperature. Organisms may in turn alter the soil or the temperature or the water content of an area.
7. Within the physical environment, interactions may be temporary, as when a cloud reduces the light intensity, or it may be permanent as when floods or earthquakes alter conditions in an area.
8. The water cycle is the movement of water from the earth to the atmosphere and back to the earth. It is very important to organisms on the

earth. It is also important that man understand the cycle so he will not be instrumental in creating large wastelands. Water evaporates from the bodies of water and from rivers and vegetation. Later it returns to the earth in precipitation. Some water runs into rivers or lakes, while other water sinks into the ground to raise the water table from which our wells and springs draw water. The cycle is repeated, but in the interim, water is used by many living organisms.

9. As the green plant fixes carbon dioxide in photosynthesis, oxygen is released to the atmosphere. The oxygen is used by the animals during respiration and carbon dioxide is released. When plants and animals die and decay, the carbon is released as carbon dioxide in the atmosphere.
10. Nitrogen forms proteins and makes up 78 percent of the air. However, free nitrogen cannot be used by plants or animals. The understanding of the ways in which organisms use nitrogen is important to the horticulturist and farmer as well as the biologist.

ANSWERS TO APPLYING PRINCIPLES AND CONCEPTS (Page 671)

1. Answers will vary depending on the

locality, but most will probably describe a lake.

2. Biologists speak of a balanced aquarium or terrarium as a closed ecosystem. However, energy is entering the system in the form of light, so it is not actually a closed system.
3. Annual variations in populations may occur as the result of an increase (or a decrease) in the number of predators (or carnivores). Unusual physical factors such as a hard winter may decrease a given population. An unusually heavy rain on a desert may produce a spring of beauty not seen for many years.
4. He chooses a number of representative small sections in which he counts each individual of a species. Then he can average the sections counted and make a statement that a given species occurs in an area in a density of a certain number per square foot.
5. The shore region of a lake is a wet environment, perhaps even warm in the winter. Nitrogenous wastes and decaying organisms at the water's edge allow a growth of algae and larger plants. The deep-water bottom region may remain in constant darkness so that no plants can carry on photosynthesis. However, the temperature may be constant. Organisms living there depend on food produced above and filtering down to them.

Guide to Laboratory Investigations for Chapter 48

INVESTIGATION 48-1

The Water Cycle

Scope of the Investigation This Investigation is designed to familiarize the student with the natural cycling of water which occurs between the earth and the atmosphere, as discussed on pp. 664-665 of the text. The student is also alerted to the role of various conservation practices in maintaining the water cycle. If the student pursues Parts 2 and 3 he will gain insight into the roles of atmospheric conditions and green plants in the water cycle.

Approximate time required Part 1 should be completed by the average student within 30-40 minutes.

Part 2 will require approximately 20 minutes to set up, and 30 minutes to determine results 24 hours later. If desired, this Part can be repeated for five consecutive days.

Part 3 will require approximately 20-30 minutes to set up, and daily observation for several days.

A Part 1 The Water Cycle and Conservation

Suggestions for procedure. Students should be provided with colored pencils and should diagram the water cycle in Fig. 48-1-a according to instructions in the student manual, taking care to label the type of water with the proper color and letter.

Student observations—answers to questions.

- (a) Topsoil absorbs water; loss of topsoil leads to more runoff and less water entering the water table as ground water.
- (b) Loss of vegetation also decreases the amount of water held by the soil as ground water.
- (c) They retain runoff water naturally, and absorb overflow from flooding.
- (d) No. They should be covered with natural vegetation which would aid in holding both water and topsoil.
- (e) They break the fall of heavy rains on the surface and hold the soil in place, thus aiding water in moving into soil rather than running off.
- (f) Floods carry water off the land into rivers and oceans. Thus the water does not seep into the soil and the level of ground water is lowered.
- (g) Topsoil absorbs water very well. As a result, water does not run off, causing floods, but remains in the soil as a protection against future drought.

B Part 2 Factors in the Rate of Evaporation

Suggestions for procedure. A shallow pan with a capacity of at least 500 ml, a screen, and a 500-ml graduated cylinder are necessary for this Part. Students should select an area for the pan where it will be fully exposed to the sun and air movements. The pan should be filled and covered as directed, left for 24 hours, and the contents measured and recorded. Local weather conditions should be determined and recorded. It is desirable to repeat this procedure for several days. Note the suggestions in the student manual for extending the scope of this Investigation.

Interpretation. Students should discover that the rate of evaporation increases with higher temperatures, lower humidity, and greater wind velocity.

B Part 3 Influence of External Factors on the Rate of Transpiration from Plants

Suggestions for procedure. Students will need sprigs of an herbaceous plant with a firm stem such as geranium, coleus, or begonia, or a woody stem such as pine, fir, or cottonwood. In addition to regular laboratory apparatus, they will need a small electric fan. The apparatus should be set up as directed in the student manual. Note that some of the stem should be cut off under water, and the sprig placed in the bottle or flask very quickly. This prevents any air-blocked vessels and allows the water to flow freely up the xylem. Note that the water level and air temperature should be recorded daily, and a graph made plotting the amount of water lost against the amount of time passed. Students should be certain that the bottle or flask is full of water and that the water level can be measured in the pipette before they begin each new section of this study. The fan can be used to vary the air currents over the leaves, and various places in the room can be used to alter the temperature and light intensity. Graphs should be used to show these results also.

Analysis and conclusions. Students should note increases in water lost by transpiration with increased light intensity, temperature, and air currents. If plants are going to lose a great deal of water due to any or all of the above factors, they must have a good water supply in order to survive. Also, large areas of vegetation tend to make the surrounding air moist.

INVESTIGATION 48-2

The Carbon-Oxygen Cycle

Scope of the Investigation This Investigation is designed to give the student experience in constructing closed environments and a closed ecosystem, which he studied on pp. 660-667 of the text. He should observe the effects of one organism on another, and develop an appreciation of the carbon-oxygen cycle which normally exists in nature.

Approximate time required Part 1 should take about 30 minutes to prepare on the first day, and a few minutes of observation daily for five days.

Part 2 will require approximately 50-60 minutes to set up, and a few minutes daily to adjust the environment. Once the aquarium is truly balanced, it may be observed without disturbing it for as many weeks or months as desired.

A Part 1 Study of a Closed Ecosystem

Suggestions for procedure. Students will require living fresh water snails, vigorously growing terminal sprigs of elodea or another suitable water plant, pond water, a heat source, and paraffin, in addition to standard laboratory equipment. The three culture tubes should be prepared and sealed as directed in the student manual. Be sure the snails are rather small and the elodea is green and healthy. Observations should be recorded in the table provided.

Student observations—answers to questions.

- (a) No.
- (b) The green plants provide food and oxygen for the animals.
- (c) Yes.
- (d) Yes.
- (e) The green plant uses the carbon dioxide from the snail's respiration for photosynthesis.
- (f) Yes.
- (g) The green plant produces oxygen by photosynthesis and uses oxygen in respiration. Carbon dioxide produced during respiration is used in photosynthesis. However, the rate of photosynthesis greatly exceeds that of respiration when there is an abundance of both gases and light. Thus in a closed environment, the rate of photosynthesis would be greatly reduced.
- (h) Decomposition is necessary to reduce certain organic compounds to forms that can be used by living things. If it were not for decomposition, soon all essential materials would be tied up in complex organic compounds.

B Part 2 Preparing a Balanced Aquarium

Suggestions for procedure. Small fish, snails, various small aquatic animals, water plants such as elodea and *Vallisneria*, a large wide-mouth jar or aquarium, clean coarse sand, and pond or aquarium water are the supplies required for Part 2. It is suggested that the jar or aquarium be as large as possible and still be practical. Plants should be rooted in two inches of coarse sand. Students should be warned against putting too many fish in the aquarium. A general rule is one inch of fish per gallon of water. Thus a four-gallon jar or aquarium would take either two 2-inch fish or four 1-inch fish. Other small aquatic animals may be added, including snails and a crayfish to act as scavengers, a tadpole, and some aquatic insects. After stocking and sealing the aquarium, care must be taken to prevent excessive growth of algae. A north window is the best location. A piece of green cellophane placed at the sides will reduce the light, if necessary, and a light bulb burned over the aquarium for a few hours daily will make

up for any light deficiency. Students may find it necessary to remove some of the animals or add some more plants to attain the proper oxygen-carbon dioxide balance. Any supplementary food needed will depend upon the type of animals used. Ideally, they should feed on the plants and algae growing in the aquarium. A summary of the organisms used should be recorded in the space provided. Note that this data should be recorded only after the balanced state is reached and the plants and animals are thriving.

Interpretation. In a closed environment animals provide carbon dioxide for the plants, which in return provide the animals with oxygen and food. Waste materials from both plants and animals provide food for some scavengers, and microscopic organisms can reduce these complex substances to simpler substances which can, in turn, be used by the plants for forming more protoplasm.

Chapter 49

The Habitat

Once the cycling of materials within a system has been discussed, the concept of the habitat and the niche are presented. The students should be aware that organisms may have the same habitat but altogether different niches. Again, it is suggested that the teacher draw on examples familiar to the students.

Tolerance studies may be performed by individual students or groups and can often provide valuable data to explain the distribution of a species. A student may be assigned to select an area and plot the distribution of any species of plant or animal. He may then suggest limiting factors involved, and if time permits, experimentation can be done. Crabs, for example, can survive in brackish water. A study on their limits of tolerance to lower salt concentrations might enable a student to predict the distance upstream a crab might travel.

As food chains and the pyramids of numbers and biomass are discussed, it is suggested that the teacher diagram them on the chalkboard as the students make suggestions. It will often surprise the students when they realize that examples of these concepts can be found in their backyards or neighborhood parks.

P. 672, left column: Using ingenuity and originality, students can make habitat models of organisms.

P. 672, right column: Game management can be discussed as a vocation. Many teen-age boys dislike the idea of being

confined indoors. All along the course opportunities in biology can be pointed out—forest ranger for private companies or the government, climatologist, Fish and Wildlife Service researcher or worker in the field, national park ranger who deals with the public. Consult vocation books and government bulletins dealing with positions in the biological field (for both men and women).

P. 680, left column: Unforeseen results of improving the living standard by improving wages are illustrated by recent events in Egypt where the improved wages have led to a demand for more and better quality, and so to a food shortage.

P. 682, left column: Use colored films or pictures to show protective coloration, countershading, protective resemblance, and mimicry. Where possible, use live animals.

Suggested Films

Energy Relations (col, 28 min) AIBS McGraw-Hill

Limiting Factors (col, 28 min) AIBS McGraw-Hill

Mimicry and Other Evidence (col, 28 min) AIBS McGraw-Hill

Nature's Plan (col, 15 min) EBF

Plant-Animal Communities: Interrelationships (b&w&col, 13½ min) Cor

The Food Cycle and Food Chains (b&w&col, 11 min) Cor

MAJOR CONCEPTS

1. The habitat of an organism is the place where it lives.
2. The niche of an organism is the way it "earns a living."
3. Anything that is essential to organisms and for which there is competition is called a limiting factor.
4. The tolerance of an organism to environmental extremes may determine its success.
5. Soil is one of the most important factors of the environment.
6. Temperature is an important controlling factor of the environment.
7. Water is essential to life.
8. Light is a critical factor in the environment.
9. With the exception of the anerobic bacteria and a few other organisms, all living things must have oxygen for life.
10. As the earth changes, so environments and the kinds of organisms change.
11. Many of the biotic relationships involve food.
12. Energy, originally from the sun, is transferred from one living thing to another.
13. Food pyramids based on numbers of individuals or on weight indicate a condition found in an ecosystem at any particular moment.
14. On the basis of the manner in which organic nutrients are received from the environment, heterotrophs can be classified as symbionts, saprophytes, or bulk feeders.

ANSWERS TO QUESTIONS FOR REVIEW (Pages 683-684)

1. Plankton, composed of the floating organisms on a lake or ocean, forms the major food for many fish. Larger fish feed on the smaller herbivorous ones, so plankton has often been called the "grass of the seas."
2. An organism's ability to withstand a variety of environmental conditions is called its tolerance. The extremes of tolerance of organisms to various conditions determine where they can live.
3. Soils may be clay, sand, silt, or loam and support different kinds of plants.

Pines grow well in sandy soil. Beech and maple trees do well in heavy loam. Larch, white cedar, and cypress trees grow best in waterlogged soils of bogs and swamps. Redwood, yellow pine, and spruce grow in rocky, shallow soils of certain mountain slopes.

4. Several important controlling physical factors of the environment are: soil type and chemical make-up, temperature, water, light, atmosphere, and topography.
5. "Cold-blooded," or poikilothermic, animals do not maintain a constant body temperature. Their body temperatures vary with the environment. "Warm-blooded," or homoiothermic, animals maintain a relatively constant body temperature regardless of the environmental temperature.
6. Deciduous plants lose their leaves and the sap descends into the roots during the freezing temperatures of winter.
7. There are two kinds of aquatic environments: fresh-water and salt-water, or marine. Plants living in very moist environments are hydrophytes and those of the deserts or semideserts are xerophytes. Plants living in neither extremely wet nor dry environments are mesophytes.
8. Hydrophytes usually have large leaves and thin epidermal layers, while xerophytes have very small leaves, even reduced to spines, with thick epidermal layers to prevent loss of water by evaporation. Xerophytes usually have extensive root systems for absorbing water. The leaves of mesophytes are of a size in between.
9. Even organisms spending their entire lives in darkness are dependent on the energy from the sun that was used in photosynthesis. The herbivores yield the energy to carnivores, which may then be eaten by the dark-dwellers.
10. Oxygen may be a limiting factor in ocean depths where water exchange is at a minimum. Compact boggy soils have a low oxygen content.

- Deep in most soils the oxygen deficiency would inhibit organisms.
11. Changes of the earth's topography are caused by erosion, volcanic eruptions, earthquakes, and flooding. Each time the topography changes, the environment changes and so does the flora and fauna.
 12. The food chain begins with the food producers, which are then consumed by the herbivores. The herbivores are the first food consumers of the ecosystem. Next are the first- and second-level carnivores. At death, the organisms are consumed by scavengers, after which the decomposers and transformers release minerals back into the soil.
 3. Yes, although he too, has basic water, food, and oxygen needs and a limited tolerance to temperature extremes. Man has the unique advantage, however, of being able to alter conditions to suit his needs.
 4. The warm-blooded animals can extend their habitats over a wide range of temperatures and can remain active through all seasons. On a cold morning they can run from their enemies or stalk and chase prey, whereas a cold-blooded animal has to warm up.
 5. Evergreens have very small leaves and snow builds up on them in a layer. This may form an insulating blanket over the tree. Also the leaves are very oily, which decreases the freezing temperature.
 6. Plants growing in reduced light usually have larger, lighter green leaves and may grow spindly. Many plants in such areas normally have tendrils so that they climb other plants. Thick pine forests may be composed of thin, spindly trees with only a tuft of green at the very tops.
 7. The answers to this question will vary widely.

ANSWERS TO APPLYING PRINCIPLES AND CONCEPTS (Page 684)

1. The answers to this question will vary widely.
2. A knowledge of the limiting factors of specific organisms enables us to predict the environment in which we may find them. We can also predict other areas where they may be able to live. This may be of significance

Guide to Laboratory Investigations for Chapter 49

INVESTIGATION 49-1

Nutritional Relationships

Scope of the Investigation This Investigation affords an opportunity for field work. The selection of a biotic community and study of a food chain should give a better understanding of nutritional relationships studied on pp. 677-679 of the text. The construction of a food pyramid based on the food chain is a graphic illustration of the principle of decrease in mass as the pyramid reaches its peak (pp. 679 and 680 of the text). If any of the students do the C-level activity, they will observe parasitism as an example of a nutritional relationship.

Approximate time required The time required for Part 1 will depend upon the nature of the study. If the student goes into the field, he may have to collect his data on Saturday or Sunday. Schools that are fortunate enough to have different types of communities near the school may take the students out for a class period. The drawing of the food chain will require 30-40 minutes.

Part 2 will require 20 minutes.

Part 3 will require an hour and a half.

A Part 1 Illustration of a Food Chain

Suggestions for procedure. If at all possible, give the students an opportunity to do the field work rather than obtain the information from a library book or textbook. A discussion of the food habits of the organisms found is necessary for the construction of a food chain.

Student observations—answers to questions.

- (a) The sun.
- (b) It is the only organism that can use the energy from the sun and make food.
- (c) They are important in the transfer of energy to animals that feed on them and in the cycling of chemicals.
- (d) Through the decay process, they break down tissues and excretions of organisms into simpler substances.
- (e) No.
- (f) Energy, unlike matter, is used up in a food chain.

A Part 2 Construction of a Food Pyramid

Suggestions for procedure. The number and mass of each group of organisms will have to be estimated since the student cannot count or weigh all of the organisms in the community.

Student observations—answers to questions.

- (a) Only a part of the organism consumed becomes the substance or biomass of the consumer.
- (b) Autotrophs.
- (c) Second-level carnivore.
- (d) At the base.
- (e) The number of kinds of organisms living there.

C Part 3 Study of Frog Parasites

Suggestions for procedure. The live frogs may be collected or purchased from supply companies that sell live specimens.

Petri dishes may be poured with the 0.7% saline solution before the dissection. Then as the frog is dissected, the structures can be put in the solution, keeping them in their natural state and permitting the student to examine the material at another class period if necessary.

The organisms frequently found include: ticks and protozoans on the external surface, immature flukes or nematodes in the body cavity, nematodes and flukes in the lungs, flukes, nematodes, tapeworms, and protozoans in the digestive tract, flukes in the bladder, and protozoans in the kidneys. Each parasite should be studied carefully, noting any mouthparts present and their type, the presence or absence of appendages, digestive system, anus, and reproductive system.

Analysis and conclusions. Many different organisms are normally parasitic on frogs. Since the frogs usually appear healthy, the student should conclude that they do little or no harm to the frog.

INVESTIGATION 49-2

Ecological Analysis of Two Habitats

Scope of the Investigation In this Investigation the students are given an opportunity to continue field study as they choose two totally different environments for

ecological analysis. From their study of the areas, they will learn how the plants and animals interact with one another by determining their role in the community. A study of physical factors such as soil, temperature, water, and light conditions will determine their influence on the lives of the organisms (pp. 672-678 of the text).

Approximate time required If two totally different habitats are located close to the school, teams can survey the half-acre plots in 40-50 minutes. If the habitats are not near enough for study during school time, the survey can be made after school or on a weekend.

Identification of the plants collected in the areas may require from one to three hours, depending upon the student's skill in use of taxonomic keys and on the number of plants collected. To save time, the teacher can identify the plants if he knows them.

B Part 1 Comparative Study of Two Habitats

Suggestions for procedure. Since field work may be curtailed in many schools because of location and time, this study may be conducted by students who are interested in doing additional studies in ecology.

Since a great amount of data is to be collected, teams could be assigned to categories, such as trees, shrubs, and insects in a given area. The teams can pool their information in the laboratory and record it in the table provided.

Student observations—answers to questions.

(a) through (f) All answers will vary.

Interpretation. Answers will vary.

INVESTIGATION 49-3

Life in Soil Communities

Scope of the Investigation This Investigation is a thorough and intensive study of a clearly defined sample of two or more types of soil. An analysis of the populations in the various soils shows that the kinds and density of organisms may vary from soil to soil (pp. 672-674 of the text). The use of a Berlese funnel acquaints the student with an excellent tool for collecting soil organisms.

Approximate time required The collection of one sample of soil will require 20-30 minutes. If the class is divided into teams, several soil samples may be collected at one time. Teams may also be assigned to the examination of the samples. Each sample will require 40-50 minutes for examination. The Berlese funnel apparatus can be set up in 10-15 minutes. This apparatus will be left for 24 hours. Identification and counting of organisms and tabulation of data will require another 40-50 minutes.

B Part 1 Comparative Study of the Fauna in Various Soils

Suggestions for procedure. The soil samples can be divided among members of the class for examination. Be sure that they are identified as to place collected. The soil particles can be separated with forceps as the student using a hand lens looks for organisms. Using a stand magnifier may facilitate the examination.

Student observations—answers to questions.

(a) 900 square centimeters.

(b) 4,500 cubic centimeters.

Interpretation. The plant and animal populations vary according to the type of soil found in the samples.

Chapter 50

Periodic Changes in the Environment

The concept of alternating periods of activity is not a new concept for the students, as they are already quite familiar with nocturnal, diurnal, and seasonal variations in the activities of various plants and animals. After they list local organisms that show periodicity, a discussion should bring out hypotheses as to the causative factors. In many examples the students will say that the sun causes the rhythms. Be sure to ask them to reconsider the statement in terms of the moon or the length of daylight. Thus, the students can begin to think about factors that can be measured and examined critically.

Next, the class should be asked to think about how and in what organs the light strength or duration is interpreted. What physiological changes are involved? In plants, for example, there are no eyes to receive the stimulus of light and no brain to interpret it. Can plants synthesize by moonlight? Such discussions should lead into the hypothesis of biological clocks and how this idea can be tested. Perhaps some of the students would like to devise and carry out experiments testing the "memory" of rhythms.

Changing biotic communities and the value of periodicity in such occurrences as migration or breeding habits should be well understood by the students. Reports on various hypotheses for bird migration can be interesting and can also stimulate further discussion.

The topic of succession is always interesting because it shows that populations (except for those in the climax condition) are on the move; changes are constantly occurring which involve the interaction between the biotic and physical factors of the environment, as well as within the biotic community. Succession may be studied by examining a hay infusion for ten minutes a day over a period of two weeks. This may become an individual project for an interested student. Succession may also be studied by examining a cleared field or a burned area or a lake or pond. Students

should look for examples in the vicinity of their homes.

P. 686, left column: Activities of plants also vary. Some flowers bloom for only one day, like the hibiscus and day lily, while some bromeliad flowers last for several weeks.

P. 687, left column: It is surprising to learn of the abundance of life in arctic regions. The growing season may be short but plants encompass the major function of reproduction in very short time intervals.

P. 688, Fig. 50-3: Bats hibernate and if a place of hibernation is nearby, it makes for a fascinating field trip. In abandoned mines and caves the animals cling upside down to the roofs and, in some instances, appear frozen to the ceiling. Bats make an interesting topic for a talk to the class or for a student report because of their unusual habits and the experiments performed on them. If treated properly, a bat can be kept for several weeks and its behavior observed.

P. 689, left column: The migration of animals makes international agreements necessary. When there is poaching, animosity is built up between nations. Students should be encouraged to bring in newspaper articles for class discussion.

P. 690, right column: Migration sometimes raises problems for man. Lights directed at tall monuments have to be turned off during the migratory season because they cause birds to dash themselves against the monuments. The Washington Monument and the skyscrapers in New York City are problems during migration.

Suggested Films

Distribution of Plants and Animals (b&w&col, 16 min) EBF

Plant and Animal Distribution (col, 28 min) AIBS McGraw-Hill

Succession From Sand Dune to Forest (b&w&col, 16 min) EBF

MAJOR CONCEPTS

1. Periodic changes in communities are brought about by regular variations in light, temperature, and climatic conditions.
2. Physical factors may act as stimuli or inhibitors which affect the behavior of organisms.
3. There are still many challenging unsolved questions regarding rhythmic behavior in plants and animals. Rhythmic behavior sometimes continues even when an animal has been placed in a laboratory under constant conditions.
4. Animals and plants meet seasonal environmental changes in various ways.
5. Many birds, mammals, and some insects migrate.
6. Biologists believe that the sun guides birds on their daylight flights and they may use the stars to guide them at night.
7. The moon is largely responsible for tides and, therefore, has an influence on many organisms in large bodies of fresh water and in the oceans.
8. Many reproductive cycles of plants and animals are associated with seasonal changes and occur in an annual rhythm.
9. In cleared areas an orderly progression of living things occurs until a balance is achieved and the climax vegetation dominates the flora. This change of living forms is succession.

ANSWERS TO QUESTIONS FOR REVIEW (Page 698)

1. The owl and hawk do not compete with one another because they occupy similar niches but at different times.
2. When the white-footed mouse is kept in constant darkness, its waking and sleeping periods continue as if it were exposed to normal periods of daylight and darkness.
3. In equatorial regions the length of day and night is nearly equal, and temperature is less variable than in other regions. The warm, moist regions on the equator provide other requirements for a wide variety of organisms. Seasonal changes are slight in equatorial regions.
4. Animals meet seasonal changes by either adjusting or moving away. Many insects die during the first freezing nights of winter, but many find crevices or hollow trees for protection. Some spend the winter under the frozen ice of ponds. The honey-bee maintains the temperature in the hive by the numbers of individuals. The eastern cottontail rabbit, white-tailed deer, and cardinal find protection in the deep woods during extreme conditions. Bears hide in caves. Ground squirrels, chipmunks, woodchucks, and many reptiles and amphibians hibernate. The monarch butterfly and many birds migrate.
5. Both hibernation and estivation are terms indicating that an animal enters a period of deep sleep. The body metabolism slows, and heart rate and respiration decrease. The animal loses consciousness. Hibernation occurs in the winter and estivation occurs in the summer.
6. Although the monarch's behavior has been attributed to instinct, the factors causing the migrations and the navigating ability of these butterflies are not understood.
7. The oceans and large bodies of water are affected by lunar rhythms, which produce tides.
8. Grunion spawn from March to August on the second, third, and fourth nights of the highest night tides. Thus the rhythm is referred to as lunar periodicity.
9. Periodicity may bring organisms together for reproduction, as in the swarming of the grunion. Male and female oysters, marine worms, sea anemones, and many others release their gametes into the water at the same time. Such periodicity is essential if these species are to continue.
10. Succession can be studied by clearing off a piece of land or a rock in the ocean and observing the passing parade of organisms inhabiting the area. Succession may be studied in a jar of water, or in the field by examining a large area, determining the climax species, and then theoriz-

ing about the stages that have occurred prior to the climax. Succession of ponds and lakes can be studied by extending observations from the lake out to the climax population. Areas of earthquakes or volcanic activity offer large areas where succession can be studied.

ANSWERS TO APPLYING PRINCIPLES AND CONCEPTS (Page 698)

1. The major reason that man's activities are not entirely governed by external rhythms is that he can alter his environment to suit his needs. Electric lights enable him to produce summer-blooming flowers in the winter. He can preserve foods for consumption all year.
2. Nocturnal animals have a keen sense of hearing and smell. Their eyes are adapted for seeing in dim light.
3. The desert and arctic treeless plain are similar in that they are actually biological deserts. Water is scarce. In the desert the water is not available to organisms because it is too deep and in the arctic plane, the water is all frozen, so that it is useless to plants.
4. Migration may be prompted by food needs, climatic changes, or breeding habits. It has been theorized that decreasing daylength in many areas shortens the time during which birds can hunt for food. Also during this time the temperature is dropping and the metabolic rate is increased. Therefore, the birds find less food, and the food requirement is greater—thus, migration.
5. The answers to this question will vary depending on the locality.
6. The answers to this question will vary depending on the locality.

Chapter 51

Biogeography

Many examples of different adaptations to dispersal can be found among local flora and fauna. After the students list examples, they should examine the area within the dispersal range to determine if the environmental conditions are favorable to the growth of the species in consideration.

The concept of biomes and the altitudinal and latitudinal gradients is not only interesting, but is important in understanding the relationship between the physical and biotic factors of the environment. In turn, the influence of the flora of a biome on the fauna is significant. Biomes may be characterized by the climax vegetation and the types of animals living there can be predicted. However, biomes are also characterized by the environment, e.g., freshwater, marine, desert. Factors characterizing each biome and some organisms found in each may be listed on the chalkboard. Discussions will then bring out specific adaptations. Again, these concepts will be more meaningful to the students when they can be applied to local organisms.

P. 660, right column: Have a chart

made showing the biosphere with representative forms drawn or pasted.

A special project can be made of the study of a nearby lake or pond. Consult a reference on limnology. This subject is sometimes taught as a separate college course but it can be introduced here. A study of a temporary pond for succession has already been suggested.

P. 663, right column: Filled-in swamps do away with feeding and nesting sites for birds, eliminate resting places for migrating birds, and lower the water table.

Man takes advantage of the fact that the chemistry of water varies when he sets aside areas for health spas. This is true around the world.

P. 699, left column: Review seed dispersal (Chapter 26).

P. 700, left column: Individual or group studies may be made by first selecting an organism and then making a circle (its radius determined by dispersal distance) to represent the area within which an offspring might be found. It may be easier for students first attempting such a

study to use plants. A diagram of streets or identifying characteristics, such as rivers, streams, large rocks, and highways, should be put in the circle. Then areas thought to be favorable for the growth of a particular organism can be colored in the circle. The next step involves a search of the area and making another diagram, coloring in the actual distribution of the species being investigated. These two diagrams can be compared and many questions regarding discrepancies will arise. This presents an opportunity for hypotheses, a return visit to certain areas, and recommendations for experimentation.

P. 701, Fig. 51-1: Explain and use pictures or a film on life at the treeline in the United States or other countries like Switzerland or Peru.

P. 704, Fig. 51-4: Specimens of Spanish moss will keep well and can be used in class for several purposes (taxonomy, habitat study, and use of Latin in science, since the English name is a misnomer).

P. 705, right column: Report on the temperate rain forest of Olympic National Park and compare with El Yunque in Puerto Rico which was mentioned earlier.

P. 707: The ocean varies in its salinity. Oceanography is a field only now coming into its own in importance as man searches for new food sources and minerals. The subject is taught in some colleges as a separate course. Shifting currents affect the movement of marine organisms which in turn affect the fishing habits of man. Fish once found in great numbers off a particular coast may no longer be found there because of a change in water temperature due to shifting ocean currents. Since the United States has initiated a long-term study of the oceans, news items will appear from time to time.

Suggested Films

Marine Ecology (col, 28 min) AIBS McGraw-Hill

Plankton and the Open Sea (b&w&col, 19 min) EBF

Plant-Animal Communities: Physical Environment (b&w&col, 11 min) Cor

Plant-Animal Communities: The Changing Balance of Nature (b&w&col, 11 min) Cor

The High Arctic Biome (b&w&col, 23 min) EBF

The Tropical Rain Forest (col, 28 min) AIBS McGraw-Hill

Tundra Ecology (col, 28 min) AIBS McGraw-Hill

Where Land and Water Meet (b&w&col, 29 min) Ind

MAJOR CONCEPTS

1. Methods of dispersal are of value to a particular species because they allow new environments to be inhabited.
2. Barriers may prevent the dispersal of certain organisms.
3. Temperature ranges in the various regions of North America divide it into climatic zones.
4. Biomes are large regions identified mainly by the climax vegetation.
5. The diverse forms of life have found niches in the different terrestrial, marine, and fresh-water environments.
6. In areas where the environment is ideal for many organisms, such as a rain forest or in the intertidal zone, growing space may be a limiting factor.
7. Salt-water and fresh-water environments have opposite osmotic problems.

ANSWERS TO QUESTIONS FOR REVIEW (Pages 710-711)

1. Plants that spread by underground stems will grow in areas where there are many of their kind. Milkweed seeds or young spiders floating on silken threads will travel farther and most likely alight in an area where there are not so many of their kind. Methods of dispersal, then, determine the distance an organism may spread.
2. Bodies of salt water are barriers to many organisms such as the frog. High mountains are barriers across which many plants and animals cannot pass. For the crabs and lobsters of shallow waters, deep water is a barrier. Although many crabs and oysters can inhabit estuaries where salt and fresh water mix, they cannot travel upstream into fresh water. Lack of food may be a barrier preventing grazing animals, such as a zebra, from crossing a desert. For deer, squirrels, and other forest ani-

mals, the desert would be a climatic as well as a biotic barrier. A swift river may prevent the spread of small mammals such as mice and shrews.

3. Arctic region, including Northern Canada, part of Alaska, Greenland; temperate region, including most of Canada and the United States; semi-tropical region, including much of Florida; and the tropical region, including Mexico.
4. Altitude and rainfall.
5. Moose, deer, elk, black bears, martins, wolverines, lynxes, squirrels, voles, chipmunks, rabbits, mice, bobcats, foxes, wolves, beavers, and porcupines are residents of the taiga. Large coniferous forests of the taiga are composed of pines, firs, and spruces.
6. The coniferous forests in the United States are found, primarily, in the Great Lakes and the St. Lawrence River Valley and along the coastal ranges of Washington, Oregon, and California.
7. The eastern United States are or once were covered with large stands of deciduous trees. Today they cover much of the Appalachian Mountain chain.
8. In the United States, the grasslands occur in the Great Plains east of the Rocky Mountains.
9. Xerophytic plants form the vegetation of both hot and cold deserts. In Death Valley, the creosote bush is the climax vegetation. The typical cold desert occurs in the temperate zone, and the sagebrush is the dominant shrub.
10. Reptiles, some insects, and birds excrete nitrogenous wastes in the form of uric acid. Uric acid can be excreted in an almost dry form, thus enabling the animal to conserve water. Most mammals of the desert burrow during the day to conserve moisture. Some rodents obtain enough water from the seeds and fruits they eat.
11. Rain forests have an abundant water supply and little seasonal variation.
12. Epiphytes have thick, porous roots

adapted to catching and holding rainfall. Many have leaves arranged so that they catch water, insects, falling leaves, and other debris. The epiphytes do not take nourishment from the trees upon which they grow.

13. The intertidal zone has extremes of moisture and drying, cold and hot, and concentration of salt water.
14. Organisms living in total darkness in the depths of the ocean are dependent on other organisms inhabiting the area and on organic material filtering down from above for their food.
15. Water gets heavier (more dense) as the temperature is lowered. However, as it freezes, the density decreases so that freezing water rises. Thus, the surface of lakes may freeze solid but organisms continue to live at the bottom where the water remains unfrozen.

ANSWERS TO APPLYING PRINCIPLES AND CONCEPTS (Page 711)

1. The answers to this question will vary widely. Some students will think of: pine cone, squirrel, hawk, or coyote.
2. Rats often stow away on ships where they are transported across an ocean barrier. Rodents may occasionally be set adrift on a log and thus be transported over a barrier. A ballooning spider may be transported over a high mountain to the other side where it may find a suitable environment.
3. As the climatic regions of the earth vary from either the north or south poles to the equator, so do the principal kinds of living things. These broad zones of the same kinds of living things may be found on a high mountain at the equator.
4. If controlling insects could not be found in Hawaii, it would be well to search the area in South America where the pineapple is indigenous. Here, it might be possible to locate a biotic control.
5. The growing season is shorter in the coniferous forest but rainfall may

average 80 inches per year. In the deciduous forest rainfall is around 40 inches per year.

6. The preponderance of life at the intertidal zone creates a space problem. Many organisms such as limpets, barnacles, and sea anemones live on shells of other animals. Many crabs spend the major part of their lives on floating kelp. Limpets living at the high water mark clamp down tightly to prevent loss of water. Mussels and barnacles close their shells when ex-

posed to the warm, drying sun. Epiphytic algae are found growing on kelp and on the shells of many crustaceans.

7. Fresh-water organisms absorb water through their exposed membranes by osmosis. Therefore, they excrete large quantities of water. In salt water the organisms are in danger of dehydration as they live in water of a higher salt concentration than their own body fluids. Marine fishes excrete salts by the gill membranes.

Guide to Laboratory Investigations for Chapter 51

INVESTIGATION 51-1

Succession

Scope of the Investigation This Investigation bears out the study of succession on pp. 694 and 695 of the text as the student actually observes the day to day changes that occur in his freshwater cultures. *Colpoda* and *Colpodium* emerge as dominant forms, only to be replaced by large numbers of paramecia. Finally, in the climax condition, there are a few of several organisms, including green plants. The decline of certain populations is a graphic illustration of how organisms can alter an environment, making it unsuitable for more of the same kind, but favorable for others to move in (p. 697 of the text). This study develops one of the most important concepts in ecology—that biotic communities are not stable. There is a continual change in populations that occupy a given space.

Approximate time required Part 1 requires three weeks. To save time in examining the cultures, divide the samples among members of the class.

B Part 1 Succession of Protists and Associated Forms in a Freshwater Culture

Suggestions for procedure. Water samples should be collected as suggested in the student manual, making sure that each jar represents a different environment. All cultures should be placed in an area that receives the same amount of light, day or night. The students have already learned that physical factors influence the populations of a community. Therefore, they must determine light variations, temperature, and pH for each culture on the days that they examine them.

Student observations—answers to questions.

- (a) Should not vary very much.
- (b) Light is essential for photosynthesis in the green protists.
- (c) Temperature affects the rate of organic decay and of fermentation.
- (d) Changes in pH affect the organisms present, and others replace them.
- (e) Fermentation causes the medium to become more acid.
- (f) Bacteria and photosynthetic organisms (flagellates).
- (g) Probably three days,
- (h) Water became turbid and acid.

- (i) Fermentation.
- (j) *Colpoda* and *Colpodium*.
- (k) May have been the acid medium that favored their multiplication over other forms such as paramecium.
- (l) Release of nitrogenous wastes by organisms. Ammonia and water combined to form ammonium hydroxide which is alkaline.
- (m) Paramecia and hypotrichs.
- (n) *Vorticella*, ameba, *Daphnia*, *Cyclops*, *Epistylis*, *Stylonychia*, *Aelosoma*, *Coleps*, *Oscillatoria*, and euglena.
- (o) Probably around the eleventh day.
- (p) Food available, mechanical crowding, light, temperature, and pH.

Interpretation. Photosynthetic organisms are dominant at first. These may include some flagellates that feed on bacteria. The bacteria carry on fermentation, releasing carbon dioxide which combines with hydrogen to form carbonic acid. A favorable medium is created for the growth of ciliates; the dominant ones at first are *Colpoda* and *Colpodium*. These live for a short time and are replaced by paramecia and hypotrichs. The paramecia die off from the accumulation of their own wastes. As the medium becomes more alkaline, the rotifers, gastrotrichs, and crustaceans appear. Finally, the cultures become stable with the clearing of the medium. Light becomes available for the growth of blue-green algae. The cultures become stable with the numbers and kinds of organisms remaining about the same.

Chapter 52

Soil and Water Conservation

Before considering soil loss and soil conservation measures, the student should become familiar with the soil itself—its content and how it is formed. Different types of soil have already been discussed in Chapter 49. Soils of different types can be brought into class and examined for pH, mineral content, and texture, humus, and peat. Some students may wish to determine the bacteria count per gram of soil.

Following the study of soils and variations in origin, texture, and mineral content, the class is prepared to discuss various kinds of soil loss and the reasons involved. Members of the class can describe regions in which they have seen soil loss. Soil conservation measures follow logically. As each kind of soil loss is discussed, we suggest that you introduce corresponding corrective measures. Individual students may make reports or models of soil conservation practices, capillary movement of water in soil, or water-holding capacity of soils.

Water conservation problems relate directly to soil problems. The water cycle presented in Chapter 48 should be reviewed

at this time. A report or a project showing the evaporation phase of the water cycle and the influence of temperature and relative humidity on the rate of evaporation may be very helpful. Still another project might involve the making of a large outline map of the United States showing the large rivers. Show the drainage to the Atlantic in one color, the Mississippi River system and Gulf drainage in a second color, and the drainage to the Pacific Ocean in a third color. Maps of rivers and streams in your own state and county will be of great value in considering local water conservation problems. In relation to the streams, a study of the sediment content can be done.

P. 713, right column: Sometimes minerals in a soil prevent certain plants from growing. When they are removed, the vegetation changes. A good example of this is in Jamaica, where bauxite is mined. After the bauxite is removed, desirable food plants can then be grown.

P. 714, right column: Soil depletion has been suggested from time to time as one cause for the fall of some ancient civilizations such as the Mayan civilization.

P. 715, left column: Tragic results of soil loss are very evident in the suburbs where the general rule seems to be to mass produce monotonous ugliness by bulldozing. This completely removes the topsoil, which may be resold to the house owners who must enrich their soil by investing time and money.

P. 716, Fig. 52-3: The Soil Conservation Service has bulletins with further information.

P. 717, Fig. 52-5: Windbreaks are also important in the conservation of wildlife because they provide nesting sites and protective cover.

P. 717, right column: Grasses are planted to hold back the dunes as they march forward with the wind. In large desert areas, a new technique of first spraying the sand with a thin film of oil has proved effective. It keeps the sand from shifting and allows plants to gain a foothold instead of being immediately engulfed by the shifting terrain.

P. 718, Fig. 52-6: The United States Department of Agriculture has many bulletins on this subject. A list of these can be obtained by writing to them.

P. 720, right column: In localities where dams and power plants are to be built, the question of fish migration must be considered. There may also be a question as to whether the site is more valuable as a tourist attraction than as a power producer. Students may be familiar with such problems locally.

Suggested Films

Birth of the Soil (col, 11 min) EBF

Our Soil Resources (Formation and Conservation) (b&w, 11 min) EBF

MAJOR CONCEPTS

1. Supplying food to vastly increasing numbers of people is becoming an urgent problem.
2. Conservation of our topsoil is an extremely serious problem.
3. Selection of proper crops is an aid to soil conservation.
4. Repeated annual plantings of the same crop may deplete the soil of essential minerals.
5. Soil fertility may be lost as water runs through the topsoil by leaching.
6. Improper use of soil may cause erosion by wind or water.
7. If fields are cleared season after season, the organic part of the topsoil may disappear.
8. Strip cropping, terracing, planting of windbreaks, and control of runoff water have been effective measures in soil conservation.
9. Watersheds and percolation beds help to raise the level of ground water.
10. Our economy depends on agriculture and agriculture is geared to the water cycle.

ANSWERS TO QUESTIONS FOR REVIEW (Page 721)

1. Running water, freezing and thawing, and the abrasive action of particles carried by the wind cause rocks to crumble and form the mineral part of the soil.
2. Humus is formed by the decomposition of terrestrial plants. Peat is the accumulated remains of bog- and lake-dwelling plants, including sphagnum moss and sedges.
3. Row crops include corn, tomatoes, and tobacco, in which the soil is exposed between rows. Cover crops include oats, clover, wheat, and other cereal grains.
4. In past years, crops were grown over and over in the same soil. The produce was removed in the harvest. This resulted in depletion of soil minerals. Many fields were abandoned to the ravages of erosion when the minerals were depleted to the point that further crops were unprofitable.
5. Deep plowing and frequent cultivation loosen and expose the soil. Especially in sandy areas, water running through the soil causes leaching out of soil minerals.
6. Organic matter can be restored to soil by spreading manure, corn cobs, and other plant remains and by planting a crop such as grass or clover and plowing it into the soil.
7. Once rills have formed, runoff water follows the same channels and enlarges the rills into gullies.

8. Cover crops, planted between row crops in strip cropping, catch and hold water and soil running off the exposed soil in the row-crop strips.
9. Terracing is used when a steep hillside is planted in crops.
10. A large gully can be stopped by building a check dam in the lower end (several may be included in a large gully) to stop the water and allow sedimentation, and by planting the banks to prevent further enlargement of the gully.
11. Wind erosion can be controlled by planting shelterbelts or windbreaks, planting soil-binding crops, plowing the soil while it is moist and at right angles to the wind, and by irrigating fields. While these measures could be used in any region where wind erosion is a problem, they apply mostly to the Southwest and the Great Plains states.
12. Floods and droughts can be reduced or prevented by controlling soil erosion, restoring forests, restoring backwaters along the streams and rivers, restoring flood plains of rivers, building dams and reservoirs, controlling the use of ground water, and flood control measures, such as building dikes and levees.

ANSWERS TO APPLYING PRINCIPLES AND CONCEPTS (Page 722)

1. Topsoil contains soil particles which give it body and looseness necessary for proper root environment, and soil minerals which dissolve in water for entry into the plant. These are necessary in chemical processes of the plant. Organic matter in topsoil makes it loose and soaks up water necessary for plant growth.
2. A crop rotation program might include corn, grown as a crop which exposes much of the soil and draws heavily on minerals. Corn can be followed by wheat, a cover crop which uses somewhat different minerals. The third year, oats might be planted as a second cover crop. The fourth year, the land should be planted in clover, cowpeas, or lespedeza. The legume crops restore nitrogen, due to the action of nitrogen-fixing bacteria on their roots.
3. When organic matter is lost from soil, the soil microorganisms die out, destroying the normal bacterial activities necessary for soil fertility.
4. In hilly agricultural areas, crops should be planted in strips laid out on the contour of hills. Contour plowing prevents water erosion which would occur if the plowing were up and down the hill. Strip cropping prevents water erosion. Crops planted in the strips may be varied year after year in a program of crop rotation.
5. During past years, forests have been cut too extensively, especially in watershed regions. Too much land has been cultivated, especially in hilly areas. Backwaters of rivers have been reclaimed and lowlands have been cultivated. Silt carried into streams in erosion areas has choked them and filled the beds with sediment. These are some of the reasons for disastrous floods. They could have been avoided by planned conservation which would not allow natural water reservoirs to be destroyed and lowlands to be cultivated. Forests should not be cut in watershed regions and only according to a scientific plan in other regions. Water conservation and flood prevention depend, further, on a soil conservation program.

Chapter 53

Forest and Wildlife Conservation

Since the forest conservation program is national in scope, students should first become familiar with the forest regions of the United States, and the kinds of trees

growing in each forest. The forest regions are shown in a map in Fig. 53-1 on p. 724 of MODERN BIOLOGY.

We continue the study of forests and

conservation with the uses of trees and forest products, emphasizing the economic importance of trees. We suggest that you discuss the causes of forest destruction and stress the deliberate and useless causes of forest fires. Under forest management, we discuss reforestation and lumbering methods, including block cutting and sustained yield.

Reports on forest trees of your region and valuable forest trees of the nation will be of great value in this study. A visit to a local or state forestry department will provide information for reports and class discussions. Abundant material on the operation of managed forests, forest preserves, forestry methods, forest products, forest tree diseases, and other forestry topics is available in pamphlet form for special study and course enrichment.

The rapid decline of the wildlife population of the United States was the inevitable result of the clearing of forests, cultivation of land and destruction of field cover, draining swamps and backwaters, polluting streams, and allowing uncontrolled market hunting for many years. In teaching this chapter, consider these and other reasons for the destruction of wildlife. Determine which causes were necessary, which were unwise and unnecessary, and which were deliberately destructive. The discussion should continue with consideration of the extent to which we can restore wildlife in a land of extensive agriculture and large suburban and urban areas.

The first consideration in fish conservation is the condition of waters and aquatic habitats. The student should understand what makes a lake or stream productive, since there is no need to stock waters that are unfit for fish to live and reproduce in. Discuss all the characteristics of a productive lake—its deep waters and shallow backwaters, vegetation, and food supply. This should include listing of native fish of your region and classification as forage fish, food fish, game fish, etc. This can be accomplished in a class discussion or by means of slides or projected pictures. Study the fishing laws of your state and the value of each of the laws. Consider too, the program of fish conservation in your state, including hatcheries and areas which are stocked regularly. These data should be

available at your state conservation department.

We have emphasized the conservation of song birds, waterfowl, and upland game birds in this chapter because of their enormous economic importance. Discussion of this area of wildlife conservation should include bird laws and the work of various bird societies.

In dealing with conservation of mammals, including big-game mammals, we must consider cover and food supply. How many smaller mammals can live in city parks and small farm woodlands? How much cover can be left around fields in highly developed agricultural areas? These are questions the class should discuss. Conservation of big-game mammals involves extensive preserves. Many of these are found in national parks. The national parks may be located on a map. This is of value not only from the standpoint of conservation education, but travel and recreation as well. Point out to the students that many animals are killed on our highways each day.

P. 724, left column: Look up recent legislation pertaining to conservation in newspapers and periodicals. These accounts can be of special interest if they pertain to local conditions.

P. 728, left column: Review biological controls: Introduction of natural enemies; Introduction of disease in the undesirable species; Use of scents and lures in traps; Use of sound in traps (buzzing of female mosquito to trap males); Sterilization of males and their release to allow mating; infertile eggs are produced.

P. 729, right column: Charcoal from wood or coconut shells is used in cigarette filters.

P. 730, left column: Amber is used today for jewelry. It also may serve as a record of the past, since it sometimes contains fossil insects.

P. 737, right column: The Hudson Bay Company records have been used to show the prevalence of fauna and cycles of fur bearers. These records have been used in the investigation of the correlation of sunspots and animal cycles.

Suggested Films

Conservation of Natural Resources (b&w, 11 min) EBF

Seeds of Destruction (b&w&col, 10 min)
EBF

MAJOR CONCEPTS

1. In the past natural balance has unknowingly been upset by man. With the knowledge of ecology that we are now acquiring, we have a responsibility to future generations to restore that balance.
2. Forests are now regarded as a crop.
3. Since forest fires destroy standing timber and consume the seeds and young trees of the future forest, each of us must do our part to prevent them.
4. Good cutting practices actually improve the value of our forests.
- X 5. Insects and grazing and gnawing animals may damage large sections of forests.
6. Since natural reforestation is a slow process, many areas are planted with seedlings.
7. We use forests and forest products in many ways.
8. Forested land helps control the water supply.
9. Game regulations insure the preservation of wildlife for the enjoyment of future generations.
10. Industries have been responsible for unnecessary destruction of many organisms in streams and surrounding areas.
11. In many areas depleted of wildlife, restocking has returned a balance.
12. Knowledge brought about by education and an appreciation for nature are important allies in our conservation programs.

ANSWERS TO QUESTIONS FOR REVIEW (Page 740)

1. Causes of forest fires include: incendiary fires, debris burners, smokers, lightning, campers, railroads, and lumbering. Incendiary fires are deliberately set. Debris burners, smokers, campers, and lumberman cause fires through carelessness. Fires resulting from railroads and lightning are unavoidable. Lightning is the only natural cause. Fires may be prevented by enforcing rigid regulations regarding throwing away lighted tobacco, burning brush and debris, and building camp fires. The

forests must be patrolled against vandals and incendiary fires. Fire rangers should guard the forest at all times.

2. If two forest rangers at different locations sight a fire, the point at which a straight line from each of them crosses indicates the location of the fire.
3. Forest insect enemies include: the sawfly, bark beetle, woodboring beetle, western pine beetle, gypsy moth, browntailed moth, tent caterpillar, tussock moth, and hemlock looper.
4. In improvement cutting, in a managed forest, trees of undesirable species, crowded trees, crooked trees, damaged trees, and diseased trees are removed.
- X 5. Whole sections of a forest are removed by block cutting when the trees are mature and of the same age, as in a forest planted in a reclaimed area.
6. Charcoal, wood alcohol, acetic acid, oxalic acid, and lampblack.
7. The principal products of pine distillation include: turpentine, rosin, and tar. Nearly all of these come from the southern forest.
8. The chestnut, chestnut oak, eastern hemlock, and tanbark oak.
9. A productive stream must have varied water environments, such as deep water, shallow pools, channels, and backwaters. These are necessary to support the variety of plants and animals which form the food chain, extending from microorganisms to large predatory fish.
10. Lowering of the water table causes the shallow backwaters of a lake or stream to dry out, destroying much of the food supply which originates in these waters, as well as spawning areas for larger fish.
11. A fish ladder is a series of water terraces broken by projecting plates. A fish can ascend the ladder by a series of short leaps.
12. Farm ponds are usually made in a low place in the corner of a field. Earth is piled on the low sides to form banks.

13. The ivory-billed woodpecker, whooping crane, prairie chicken, and California condor.

ANSWERS TO APPLYING PRINCIPLES AND CONCEPTS (Page 740)

1. In a forest managed on a sustained yield basis, every tree is a good timber species. Trees are properly spaced as a result of thinning out. The forest is free of damaged, crooked, and diseased trees. Trees are harvested as they mature. A virgin forest, on the other hand, contains many over-aged and dying trees. trees with no commercial value, crowded trees, diseased trees, etc.

2. Sportsmen are among the most ardent supporters of the wildlife conservation programs. They are aware of the problems involved and, in the interest of hunting and fishing, work toward correction of the problems. The fees they pay for hunting and fishing licenses help support the conservation programs.
3. Big-game mammals such as deer require extensive ranges. Food supply and danger of overstocking, as well as interference with agricultural activities, are serious problems. In some areas deer destroy large amounts of farm crops.
4. Predatory birds and animals are essential in maintaining a proper balance in game management.

Suggested References for the Teacher—Unit VIII

Books

Ager, D. V. *Principles of Paleoecology*. McGraw-Hill Book Co., New York, 1963

Allee, W. C. *Social Life of Animals*. Rev. ed. New American Library of World Literature, New York, 1958

Andrewartha, H. G., and Birch, L. *The Distribution and Abundance of Animals*. University of Chicago Press, Chicago, 1954

Andrewartha, H. G. *Introduction to the Study of Animal Populations*. University of Chicago Press, Chicago, 1961

Andrews, Roy Chapman. *Nature's Ways*. Crown Publishers, New York, 1951

Arnov, Boris, Jr. and Mindlin, Helen M. S. *Wonders of the Ocean Zoo*. Dodd, Mead, and Co., New York, 1958

Aubert De La Rüe, E., Bourlière, F., and Harray, J. P. *The Tropics*. Alfred A. Knopf, New York, 1957

Barnett, L., and Life Editorial Staff. *The World We Live In*. Time, New York, 1955

Bates, M., and Abbott, D. P. *Coral Island*. Charles Scribner's Sons, New York, 1958

Bates, M. *The Forest and the Sea*. Random House, New York, 1960

Bates, M. *The Nature of Natural History*. Rev. ed. Charles Scribner's Sons, New York, 1962

Bates, M. *Where Winter Never Comes*. Charles Scribner's Sons, New York, 1952

Beaufort, L. F. *Zoogeography of the Land and Inland Waters*. Sidgwick & Jackson, Ltd., London, 1951

Beebe, W. *Unseen Life of New York as a Naturalist Sees It*. Little, Brown, and Co., Boston, 1953

Bennett, G. W. *Management of Artificial Lakes and Ponds*. Reinhold Publishing Corp., New York, 1962

Benton, A. H. and Werner, W. E. *Principles of Field Biology and Ecology*. McGraw-Hill Book Co., New York, 1958

Berrill, N. F. and Berrill, Jacquelyn. *1001 Questions Answered About the Seashore*. Dodd, Mead and Co., New York, 1957

Braun, E. L. *Deciduous Forests of Eastern North America*. The Blakiston Co., New York, 1950

Broadhurst, P. L. *The Science of Animal Behavior*. Penguin Books, Baltimore, Md., 1963

Browning, T. O. *Animal Populations*. Harper and Row, New York, 1963

Burns, W. A. (ed.). *The Natural History of the Southwest*. Franklin Watts, New York, 1960

Burton, Maurice, *Animals and Their Behavior*. Longmans, Green and Co., New York, 1950

Buxton, P. A. *Animal Life in Deserts*.

- Princeton University Press, Princeton, N.J., 1955
- Carpenter, Shirley and Neurath, Marie. *Icebergs and Jungles*. Hanover House, Garden City, N.Y. 1958
- Carr, A. *Guideposts of Animal Navigation*. D. C. Heath & Co., Boston, 1962
- Carson, R. *Silent Spring*. Houghton Mifflin Co., Boston, 1962
- Carson, R. *The Sea Around Us*. Simon and Schuster, New York, 1958
- Carthy, J. D. *An Introduction to the Behaviour of Invertebrates*. The Macmillan Co., New York, 1958
- Chase, G. D., Riptuper, S., and Sulcoski, J. W. *Experiments in Nuclear Science: The Teacher's Guide*. Burgess Publishing Co., Minneapolis, 1964
- Coker, R. E. *Streams, Lakes, Ponds*. University of North Carolina Press, Chapel Hill, N.C., 1954
- Cragg, J. B. (ed.). *Advances in Ecological Research*, Vol I. Academic Press Inc., New York, 1962
- Crisler, Lois. *Arctic Wild*. Harper and Row, New York, 1958
- Dansereau, P. *Biogeography: An Ecological Perspective*. The Ronald Press Co., New York, 1957
- Darlington, P. J. *Zoogeography*. John Wiley & Sons, New York, 1957
- Dethier, V. G. and Stellar, E. *Animal Behavior, Its Evolutionary and Neurological Basis*. Prentice-Hall, Englewood Cliffs, N.J., 1961
- Dice, L. R. *Natural Communities*. University of Michigan Press, Ann Arbor, Mich., 1952
- Dooley, Thomas A. *The Edge of Tomorrow*. Farrar, Straus, and Cudahy New York, 1958
- Doukan, Dr. Gilbert. *World Beneath the Waves*. John deGraff, New York, 1958
- Editorial Staff of *Life* and Barnett, Lincoln. *The World We Live In*. Simon and Schuster, New York, 1955
- Ekman, S. P. *Zoogeography of the Sea*. Translated by Elizabeth Palmer. Sidgwick & Jackson, Ltd. London, 1953
- Elton, C. S. *The Ecology of Invasions by Animals and Plants*. John Wiley & Sons, New York, 1958
- Errington, Paul L. *Of Men and Marshes*. The Macmillan Co., New York, 1957
- Farb, P. *Living Earth*. Harper and Row, New York, 1959
- Follansbee, H. *A Laboratory Block on Animal Behavior*. BSCS, Boulder, Colo., 1961
- Frey, D. G. (ed.). *Limnology in North America*. University of Wisconsin Press, Madison, Wis., 1963
- Gates, D. M. *Energy Exchange in the Biosphere*. Harper and Row, New York, 1962
- George, W. B. *Animal Geography*. William Heinemann, Ltd., London, 1962
- Goetz, Delia. *The Arctic Tundra*. William Morrow and Co., New York, 1958
- Good, R. D. *The Geography of the Flowering Plants*. Longmans, Green & Co., Ltd., London, 1953
- Gray, J. *How Animals Move*. Cambridge University Press, New York, 1953
- Greig-Smith, P. *Quantitative Plant Ecology*. Academic Press Inc., New York, 1957
- Hanson, H. C. and Churchill, E. D. *The Plant Community*. Reinhold Publishing Corp., New York, 1961
- Hardy, A. C. *The Open Sea, Its Natural History*. William Collins Sons & Co., Ltd., London, 1956
- Harlow, William M. and Harrar, Ellwood S. *Textbook of Dendrology: Covering the Important Forest Trees of the United States and Canada*. 4th ed. McGraw-Hill Book Co., New York, 1958
- Hausman, Leon. *Beginner's Guide to Seashore Life*. G. P. Putnam's Sons, New York, 1950
- Hylander, Clarence. *Sea and Shore*. The Macmillan Co., New York, 1950
- International Oceanographic Congress, New York. *Oceanography*. (Publication No. 67), ed. Mary Sears. American Associations for the Advancement of Science, Washington, D. C., 1961
- Jaeger, E. C. *The North American Deserts*. Stanford University Press, Palo Alto, Calif. 1957
- Kendeigh, S. C. *Animal Ecology*. Prentice-Hall, Englewood Cliffs, N.J., 1961
- Klopfer, P. H. *Behavioral Aspects of Ecology*. Prentice-Hall, Englewood Cliffs, N.J., 1962

- Krutch, J. W. *The Great Chain of Life*. Houghton, Mifflin Co., Boston, 1957
- Kumlien, L. L. *The Friendly Evergreens*. Rev. ed. Holt, Rinehart and Winston, New York, 1954
- Lack, D. *The Natural Regulation of Animal Numbers*. Oxford University Press, New York, 1954
- Lane, Ferdinand C. *The Story of Trees*. Doubleday and Co., Garden City, N.Y., 1952
- Lorenz, K. Z. *King Solomon's Ring*. The Thomas Y. Crowell Co., New York, 1952
- Malthus, T., Huxley, J., and Osborn, F. *On Population: Three Essays*. New American Library of World Literature, New York, 1960
- Meyerriecks, A. J. *Courtship in Animals*. D. C. Heath & Co., Boston, 1962
- McClung, Robert. *Animals and Their Young*. Random House, New York, 1958
- Morrow, Betty. *See Up the Mountain*. Harper and Row, New York, 1958
- Neal, E. G. *Woodland Ecology*. Harvard University Press, Cambridge, Mass., 1958
- Needham, J. G. and Needham, P. R. *A Guide to the Study of Fresh-Water Biology*. 5th ed. Holden-Day, San Francisco, Calif. 1962
- Nottingham, Eng., University School of Agriculture: *Soil Zoology*. ed. D. K. M. Kevan. Butterworth & Co., London, 1955
- Osting, H. J. *The Study of Plant Communities*. W. H. Freeman & Co., San Francisco, Calif., 1956
- Peattie, Donald Culross, *A Natural History of Western Trees*. Houghton, Mifflin Co., Boston, 1953
- Platt, Rutherford. *1001 Questions Answered About Trees*. Dodd, Mead and Co., New York, 1958
- Popham, E. J. *Some Aspects of Life in Fresh-Water*, 2nd ed. Harvard University Press, Cambridge, Mass., 1961
- Reid, G. K. *Ecology of Inland Waters and Estuaries*. Reinhold Publishing Corp. Book Division, New York, 1961
- Richards, P. W. *The Tropical Rain Forest*. Cambridge University Press, London, 1955
- Roe, A. and Simpson, G. G. (ed.). *Behavior and Evolution*. Yale University Press. New Haven, Conn., 1958
- Articles*
- Beyers, Robert, J. "The Microcosm Approach to Ecosystem Biology." *The American Biology Teacher*, November, 1964
- Calhoun, J. B. "Population Density and Social Pathology." *Scientific American*, February, 1962
- Corrington, Julian D. "Nature and the Microscope." *Natural History*, March, 1964
- Davis, George H. "Management of Water in Arid Lands." *Natural History*, August-September, 1964
- Denton, Eric "The Buoyancy of Marine Animals." *Scientific American*, July, 1960
- Dietz, R. S. "The Sea's Deep Scattering Layer." *Scientific American*, August, 1962
- Dineley, David, L. "Armor-Plated and Jawless Devonian Fish." *Natural History*, August-September, 1964
- Dorf, Erling. "The Petrified Forests of Yellowstone Park." *Scientific American*, April, 1964
- Dowling, Herndon G. "Color Change: Chameleon Camouflage." *Natural History*, February, 1964
- Fournier, Paul J. "Migration in Main." *Natural History*, October, 1964
- Haag, W. G. "The Bering Strait Land Bridge." *Scientific American*, January, 1962
- Hartesveldt, Richard J. "Fire Ecology of the Giant Sequoias." *Natural History*, December 1964
- Linton, David. "Nature and the Camera." *Natural History*, May, 1964
- Llano, George. "The Terrestrial Life of the Antarctic." *Scientific American*, September, 1962
- Lowdermilk, Walter C. "The Reclamation of a Man-Made Desert." *Scientific American*, March, 1960
- McDermott, W. "Air Pollution and Public Health." *Scientific American*, October, 1961
- McElroy, W. D. and Seliger, H. H. "Biological Luminescence." *Scientific American*, December, 1962
- McNeil, Mary. "Lateritic Soils." *Scientific American*, November 1964
- Nace, Raymond L. "Water of the World" *Natural History*, January, 1964

**KEY TO TESTS
AND ALTERNATE TESTS IN BIOLOGY
1965**

Test 1 Chapters 1-2
The Science of Life and the Living Condition

1....E	15....C	29....d	43....b
2....I	16....b	30....b	44....c
3....L	17....d	31....a	45....b
4....O	18....c	32....d	46....resolution
5....A	19....a	33....b	(detail)
6....K	20....d	34....c	47....light
7....P	21....c	35....d	48....electro-
8....D	22....b	36....protoplasm	magnets
9....F	23....b	37....organism	(magnetic
10....N	24....a	38....adaptation	fields)
11....J	25....c	39....cells	49....a beam of
12....B	26....b	40....response	electrons
13....M	27....d	41....a	50....photographic
14....H	28....a	42....e	plate

Alternate Test 1

1....F	19....c	37....e	reproduce
2....H	20....d	38....d	are capable
3....L	21....b	39....c	of response
4....P	22....a	40....b	have a
5....I	23....c	41....composed of	critical
6....C	24....b	protoplasm	relationship
7....O	25....c	42....have a	with the
8....Q	26....d	cellular	environment
9....A	27....c	organization	46....gamma
10....J	28....c	43....capable of	globulin
11....M	29....a	growth	47....variable
12....G	30....c	44....have a	(experimental
13....D	31....b	definite form	factor)
14....B	32....d	and size range	48....migration
15....N	33....d	45....Have a life	49....protoplasm
16....d	34....c	span	50....abiogenesis
17....b	35....b	have the	(spontaneous
18....b	36....d	capacity to	generation)

Test 2 Chapter 3
The Chemical Basis of Life

1....E	14....H	27....c	40....b
2....I	15....D	28....b	41....d
3....M	16....b	29....d	42....b
4....O	17....c	30....a	43....c
5....B	18....a	31....b	44....b
6....A	19....b	32....c	45....a
7....Q	20....d	33....a	46....energy
8....G	21....c	34....d	47....an ion
9....F	22....b	35....c	48....cellulose
10....J	23....b	36....b	49....isotopes
11....P	24....a	37....d	50....gel
12....C	25....d	38....d	
13....N	26....c	39....a	

Alternate Test 2

1....C	14....O	27....b	40....b
2....I	15....H	28....a	41....d
3....M	16....d	29....b	42....d
4....B	17....a	30....d	43....a
5....A	18....b	31....c	44....d
6....Q	19....d	32....b	45....b
7....E	20....d	33....b	46....sol
8....D	21....c	34....a	47....compound
9....K	22....c	35....b	48....RNA
10....L	23....d	36....c	49....radioactive
11....F	24....c	37....c	50....complete
12....J	25....c	38....c	proteins
13....P	26....a	39....b	

Test 3 Chapters 4-5
The Cell Structure and Cell Environment

1....E	16....C	31....a	42....vacuole
2....C	17....C	32....d	43....nuclear
3....M	18....b	33....b	membrane
4....J	19....d	34....d	44....Golgi bodies
5....A	20....c	35....c	45....nucleus
6....H	21....a	36....osmosis	46....chromosomes
7....K	22....d	(absorption)	47....nucleolus
8....D	23....b	37....plasmolysis	48....mitochron-
9....O	24....a	38....active	drion
10....L	25....c	transport	49....endoplasmic
11....B	26....b	39....diffusion	reticulum
12....Q	27....a	40....osmosis	50....ribosome
13....G	28....b	(absorption)	
14....N	29....c	41....plasma	
15....P	30....c	membrane	

Alternate Test 3

1....E	15....G	29....b	40....active
2....Q	16....d	30....a	transport
3....F	17....b	31....d	41....C
4....A	18....c	32....c	42....E
5....N	19....a	33....e	43....I
6....O	20....c	34....d	44....A
7....L	21....d	35....a	45....F
8....D	22....a	36....osmosis	46....B
9....C	23....b	(absorption)	47....J
10....J	24....b	37....plasmolysis	48....F
11....P	25....b	38....osmosis	49....H
12....M	26....d	(absorption)	50....K
13....K	27....c	39....diffusion	
14....H	28....d		

Test 4 Chapters 6-8
Cell Nutrition, Metabolism, Growth and Reproduction

1....B	14....L	27....a	40....b
2....G	15....D	28....b	41....a
3....J	16....C	29....c	42....d
4....F	17....b	30....d	43....d
5....I	18....c	31....b	44....b
6....A	19....a	32....a	45....a
7....P	20....a	33....d	46....e
8....E	21....c	34....b	47....a
9....H	22....c	35....c	48....b
10....N	23....a	36....b	49....d
11....C	24....c	37....d	50....c
12....M	25....d	38....b	
13....Q	26....b	39....d	

Alternate Test 4

1....G	15....H	29....a	43....c
2....P	16....b	30....d	44....d
3....M	17....d	31....c	45....b
4....I	18....d	32....a	46....water
5....A	19....c	33....b	47....synthetic
6....O	20....c	34....d	phase (dark
7....J	21....a	35....b	reaction)
8....D	22....b	36....d	48....ribosomes
9....C	23....c	37....d	49....3
10....K	24....b	38....b	50....messenger
11....E	25....a	39....c	RNA
12....N	26....c	40....d	
13....L	27....d	41....b	
14....B	28....c	42....a	

Test 5 Chapters 9-10
Principles of Heredity and the Genetic Material

1....D	14....A	27....c	40....black rough
2....I	15....F	28....b	41.... <i>BBRR</i>
3....P	16....a	29....b	42.... <i>BBRr</i>
4....M	17....d	30....c	43.... <i>BbRR</i>
5....C	18....c	31....d	44.... <i>BbRr</i>
6....O	19....b	32....b	45....female
7....J	20....b	33....c	46....red
8....G	21....c	34....a	47....male
9....E	22....d	35....e	48....vermilion
10....N	23....b	36.... <i>BR</i>	49.... <i>X^rX^rY</i>
11....K	24....b	37.... <i>Br</i>	50....nondisjunction
12....B	25....a	38.... <i>bR</i>	
13....L	26....c	39.... <i>br</i>	

Alternate Test 5

1....P	15....I	29....d	41.... <i>TTY^Y</i>
2....J	16....c	30....b	42.... <i>TTY^y</i>
3....H	17....b	31.... <i>XY</i>	43.... <i>TtYY</i>
4....F	18....d	32....unit	44.... <i>TtY^y</i>
5....B	19....b	characters	45....pure red female
6....E	20....c	33....recessive	46....hyb. red female
7....C	21....d	34....linkage	47....red male
8....O	22....a	35....capsule	48....white male
9....G	23....b	36.... <i>TY</i>	49.... $\frac{1}{2}$ red
10....M	24....d	37.... <i>Ty</i>	50.... $\frac{1}{2}$ roan
11....K	25....b	38.... <i>tY</i>	
12....D	26....b	39.... <i>ty</i>	
13....L	27....c	40....tall and yellow	
14....A	28....b		

Test 6 Chapters 11-12
Genes in Human Populations and Applied Genetics

1....H	15....F	29....d	40.... <i>Bb</i> bald male
2....D	16....b	30....c	41....A
3....E	17....d	31....a	42....B
4....O	18....a	32....b	43....AB
5....N	19....d	33....d	44....carrier
6....I	20....c	34....c	female
7....Q	21....b	35....b	45....normal male
8....B	22....a	36.... <i>Nn</i>	46....diseased male
9....A	23....c	37.... <i>BB</i> normal	47....normal
10....P	24....b	male	female
11....K	25....d	38.... <i>BB</i> normal	48....carrier
12....G	26....c	female	female
13....C	27....b	39.... <i>Bb</i> normal	49....normal male
14....J	28....b	female	50....diseased male

Alternate Test 6

1....N	15....F	29....b	41....A (AO)
2....C	16....b	30....a	42....B (BB & BO)
3....A	17....c	31....b	43....AB
4....G	18....a	32....c	44....color-blind
5....I	19....d	33....b	male
6....K	20....b	34....c	45....carrier female
7....E	21....d	35....b	46....normal male
8....J	22....d	36.... <i>Ff</i>	47....normal
9....O	23....c	37.... <i>Bb</i> bald male	female
10....H	24....c	38.... <i>Bb</i> normal	48....carrier
11....D	25....a	female	female
12....L	26....c	39.... <i>bb</i> Bald male	49....normal male
13....M	27....d	40.... <i>bb</i> bald	50....color-blind
14....Q	28....d	female	male

Test 7 Chapters 13-14
Organic Variation and the Diversity of Life

1....E	15....N	29....a	43....B
2....G	16....c	30....b	44....E
3....K	17....b	31....d	45....D
4....Q	18....b	32....b	46....A
5....F	19....a	33....c	47....isolation
6....I	20....c	34....b	48....adaptive
7....A	21....d	35....b	radiation
8....D	22....b	36....e	49....convergent
9....O	23....c	37....e	evolution
10....L	24....b	38....d	50....natural
11....B	25....a	39....b	selection
12....C	26....a	40....a	
13....J	27....d	41....C	
14....P	28....c	42....D	

Alternate Test 7

1....M	14....Q	27....b	40....d
2....J	15....A	28....d	41....c
3....L	16....c	29....c	42....b
4....G	17....d	30....c	43....a
5....O	18....b	31....a	44....c
6....K	19....a	32....c	45....a
7....C	20....c	33....d	46....D
8....P	21....c	34....c	47....A
9....I	22....b	35....b	48....B
10....E	23....d	36....c	49....E
11....B	24....c	37....c	50....C
12....N	25....c	38....d	
13....D	26....b	39....c	

Test 8

Chapters 15-17

Viruses, Bacteria, and Infectious Disease

1....K	15....O	29....a	43....a
2....G	16....d	30....d	44....d
3....E	17....c	31....b	45....b
4....F	18....b	32....c	46....natural
5....C	19....d	33....c	immunity
6....I	20....a	34....a	47....active
7....M	21....d	35....b	immunity
8....A	22....b	36....d	48....passive
9....Q	23....c	37....c	immunity
10....N	24....b	38....b	49....aerobes
11....B	25....a	39....d	50....anaerobes
12....H	26....c	40....c	
13....L	27....b	41....d	
14....D	28....c	42....c	

Alternate Test 8

1....L	14....C	27....d	40....b
2....J	15....I	28....a	41....b
3....O	16....c	29....d	42....c
4....N	17....a	30....b	43....d
5....K	18....d	31....c	44....c
6....P	19....b	32....c	45....c
7....F	20....c	33....b	46....b
8....D	21....c	34....b	47....c
9....Q	22....c	35....b	48....a
10....G	23....a	36....b	49....a
11....H	24....c	37....d	50....d
12....M	25....c	38....d	
13....E	26....d	39....a	

Test 9 Chapter 18
The Protozoans

1....I	14....M	27....c	40....d
2....L	15....C	28....a	41....flagellum
3....Q	16....c	29....c	42....eyespot
4....D	17....b	30....d	43....reservoir
5....B	18....d	31....a	44....chloroplast
6....H	19....b	32....b	45....nucleus
7....F	20....a	33....a	46....cilia
8....P	21....b	34....d	47....trichocyst
9....J	22....d	35....c	48....macronucleus
10....O	23....d	36....c	49....gullet
11....K	24....b	37....b	50....contractile
12....E	25....d	38....a	vacuole
13....N	26....b	39....d	

Alternate Test 9

1....L	15....O	29....c	43....plasma
2....Q	16....b	30....d	membrane
3....A	17....b	31....a	44....nucleus
4....F	18....a	32....c	45....ectoplasm
5....J	19....c	33....c	46....contractile
6....B	20....b	34....c	vacuole
7....M	21....d	35....b	46....contractile
8....I	22....d	36....d	vacuole
9....E	23....d	37....b	47....endoplasm
10....C	24....b	38....c	48....ameba
11....D	25....b	39....b	49....sarcodina
12....G	26....c	40....b	50....pseudopodia
13....P	27....a	41....pseudopodium	(ameboid
14....N	28....d	42....food vacuole	movement)

Test 10

Chapters 19-20

The Fungi and Algae

1....F	14....P	27....b	40....c
2....N	15....C	28....c	41....b
3....G	16....d	29....a	42....a
4....J	17....a	30....c	43....d
5....A	18....b	31....d	44....d
6....M	19....c	32....b	45....c
7....O	20....a	33....b	46....d
8....E	21....d	34....a	47....b
9....H	22....c	35....b	48....e
10....K	23....d	36....c	49....b
11....Q	24....b	37....d	50....c
12....I	25....a	38....b	
13....D	26....c	39....c	

Alternate Test 10

1....P	14....C	27....d	40....c
2....J	15....E	28....a	41....d
3....Q	16....b	29....c	42....b
4....H	17....c	30....d	43....c
5....A	18....d	31....b	44....c
6....L	19....b	32....a	45....a
7....N	20....a	33....b	46....e
8....I	21....c	34....b	47....d
9....D	22....b	35....d	48....d
10....O	23....b	36....c	49....a
11....F	24....d	37....d	50....c
12....B	25....c	38....b	
13....G	26....b	39....b	

Test 11 Chapters 21-22
Mosses and Ferns, The Seed Plants

1....Q	14....K	27....c	40....c
2....M	15....E	28....d	41....b
3....P	16....b	29....b	42....c
4....I	17....c	30....b	43....a
5....G	18....a	31....c	44....c
6....O	19....d	32....b	45....d
7....D	20....d	33....d	46....c
8....L	21....b	34....c	47....e
9....H	22....c	35....b	48....b
10....B	23....d	36....b	49....d
11....F	24....b	37....a	50....e
12....N	25....a	38....b	
13....A	26....c	39....d	

Alternate Test 11

1....J	14....P	27....d	40....d
2....N	15....K	28....b	41....b
3....C	16....c	29....c	42....d
4....O	17....b	30....c	43....c
5....L	18....c	31....c	44....a
6....G	19....b	32....d	45....d
7....B	20....a	33....a	46....b
8....H	21....d	34....b	47....c
9....E	22....b	35....d	48....c
10....A	23....d	36....a	49....b
11....F	24....b	37....c	50....b
12....I	25....b	38....c	
13....Q	26....c	39....c	

Test 12

Chapters 23-24

Root and Stem Structure and Function

1....D	14....N	27....c	40....b
2....M	15....H	28....b	41....d
3....G	16....b	29....a	42....d
4....I	17....d	30....c	43....b
5....A	18....a	31....b	44....d
6....P	19....c	32....c	45....c
7....L	20....b	33....b	46....c
8....E	21....b	34....d	47....b
9....F	22....c	35....c	48....e
10....B	23....d	36....a	49....c
11....O	24....c	37....a	50....d
12....K	25....b	38....b	
13....Q	26....a	39....c	

Alternate Test 12

1....I	14....Q	27....b	40....d
2....M	15....D	28....a	41....b
3....E	16....a	29....c	42....d
4....F	17....d	30....d	43....c
5....A	18....c	31....c	44....b
6....L	19....b	32....b	45....d
7....G	20....b	33....b	46....taproot
8....M	21....a	34....c	47....cortex
9....P	22....c	35....d	48....carbonic acid
10....K	23....b	36....b	49....absorption of
11....H	24....b	37....a	water
12....C	25....b	38....c	50....apical
13....O	26....c	39....c	dominance

Test 13 Chapters 25-26
Leaf Structure and Function, Higher Plant Reproduction

1....N	14....O	27....b	40....d
2....I	15....K	28....b	41....d
3....A	16....c	29....c	42....c
4....J	17....d	30....a	43....b
5....P	18....d	31....d	44....b
6....M	19....b	32....c	45....c
7....Q	20....a	33....b	46....style
8....G	21....c	34....a	47....anthers
9....D	22....b	35....c	(stamens)
10....B	23....b	36....b	48....petals
11....E	24....a	37....c	49....sepal
12....L	25....d	38....d	50....ovary
13....C	26....d	39....b	

Alternate Test 13

1....H	15....D	29....c	43....nitrogen
2....J	16....c	30....d	44....compound
3....N	17....a	31....d	45....transpiration
4....Q	18....d	32....b	46....mechanical
5....I	19....d	33....c	dispersal
6....A	20....b	34....b	47....food for birds
7....E	21....c	35....b	and other
8....L	22....c	36....d	animals
9....F	23....b	37....d	49....clinging to
10....B	24....d	38....a	fur of
11....C	25....d	39....c	animals
12....K	26....a	40....b	49....water
13....P	27....c	41....the embryo	50....wind
14....M	28....d	42....respiration	

First Semester Final Chapters 1-26
Part 1: The Nature of Life

- | | |
|---------|----------------------------|
| 1....Q | 14....F |
| 2....C | 15....N |
| 3....I | 16....amino acids |
| 4....A | 17....carbon |
| 5....J | 18....nucleus |
| 6....K | 19....osmosis |
| 7....P | 20....water |
| 8....D | 21....neutrons |
| 9....E | 22....DNA |
| 10....M | 23....light (light energy) |
| 11....B | 24....oxygen |
| 12....O | 25....a secondary oocyte |
| 13....H | |

Part 2: The Continuity of Life

- | | |
|---------|---------|
| 26....C | 39....b |
| 27....b | 40....c |
| 28....b | 41....d |
| 29....d | 42....c |
| 30....c | 43....b |
| 31....a | 44....d |
| 32....b | 45....b |
| 33....a | 46....b |
| 34....b | 47....d |
| 35....d | 48....b |
| 36....c | 49....d |
| 37....b | 50....c |
| 38....a | |

Part 3: Microbiology

- | | |
|---------------|--------------------|
| 51....capsule | 53....parasite |
| 52....viruses | 54....anterior end |

308 KEY TO ALTERNATE FIRST SEMESTER FINAL

- | | |
|--|---|
| 55....flagella | 66....locomotion |
| 56....symbiosis | 67....alcohol |
| 57....starch (food) | 68....gene |
| 58....chlorophyll | 69....immunity |
| 59....saprophyte | 70....anaerobes (anaerobic) |
| 60....sexual reproduction (sexual stage) | 71....RNA |
| 61....contractile vacuole | 72....euglena |
| 62....spore | 73....chloroplast |
| 63....an antibiotic | 74....micronuclei (nuclear material) |
| 64....lichen | 75....plasma membrane (mēbrane surface) |
| 65....bacteriophage | |

Part 4: Multicellular Plants

- | | |
|---------|----------|
| 76....d | 89....a |
| 77....b | 90....c |
| 78....b | 91....b |
| 79....c | 92....d |
| 80....d | 93....d |
| 81....a | 94....a |
| 82....b | 95....b |
| 83....d | 96....c |
| 84....c | 97....b |
| 85....c | 98....b |
| 86....b | 99....d |
| 87....c | 100....c |
| 88....c | |

Alternate First Semester Final Chapters 1-26
Part 1: The Nature of Life

- | | |
|---------|---------|
| 1....a | 14....b |
| 2....c | 15....d |
| 3....c | 16....a |
| 4....d | 17....c |
| 5....b | 18....c |
| 6....b | 19....d |
| 7....c | 20....a |
| 8....b | 21....b |
| 9....d | 22....d |
| 10....a | 23....b |
| 11....c | 24....c |
| 12....c | 25....a |
| 13....b | |

Part 2: The Continuity of Life

26....N	39....H
27....I	40....G
28....K	41....dominant
29....L	42....fraternal
30....D	43....male
31....M	44....4
32....P	45....the inheritance of acquired characteristics
33....F	46....taxonomy (classification)
34....J	47....wing
35....Q	48....Charles Darwin
36....A	49....environment
37....E	50....X chromosome
38....B	

Part 3: Microbiology

51....d	64....c
52....d	65....b
53....a	66....c
54....c	67....b
55....b	68....a
56....c	69....b
57....d	70....c
58....b	71....b
59....b	72....c
60....c	73....d
61....c	74....d
62....b	75....c
63....c	

Part 4: Multicellular Plants

76....stigma	89....vascular tissue (conducting tissue)
77....vascular cambium	90....photosynthesis
78....phloem	91....micropyle
79....flower	92....tropism
80....monocot	93....rhizoids
81....prothallium	94....viability
82....anther (pollen sac)	95....the terminal buds
83....absorption	96....xylem
84....adventitious	97....translocation
85....water	98....cotyledon
86....leaves	99....a perennial
87....endosperm	100....cambiums
88....annuals	

Test 14 Chapters 27-29
Lower Invertebrates

1....J	14....F	27....a	40....d
2....P	15....C	28....b	41....e
3....M	16....b	29....a	42....c
4....Q	17....a	30....c	43....d
5....E	18....d	31....a	44....e
6....O	19....c	32....c	45....b
7....K	20....b	33....c	46....A
8....B	21....d	34....c	47....F
9....N	22....d	35....d	48....D
10....D	23....d	36....c	49....H
11....L	24....d	37....b	50....E
12....G	25....c	38....b	
13....A	26....b	39....b	

Alternate Test 14

1....I	14....J	27....c	40....b
2....F	15....C	28....d	41....c
3....H	16....b	29....a	42....d
4....O	17....d	30....d	43....c
5....B	18....a	31....b	44....c
6....E	19....c	32....b	45....c
7....L	20....b	33....b	46....d
8....P	21....b	34....a	47....b
9....N	22....a	35....c	48....c
10....Q	23....d	36....b	49....b
11....D	24....c	37....d	50....c
12....G	25....c	38....a	
13....M	26....d	39....b	

Test 15

Chapters 30-32

The Insects and Other Arthropods

1....D	14....B	27....b	40....c
2....L	15....H	28....d	41....d
3....Q	16....c	29....c	42....c
4....F	17....b	30....d	43....c
5....K	18....d	31....b	44....b
6....A	19....c	32....a	45....d
7....P	20....a	33....c	46....e
8....E	21....c	34....c	47....b
9....I	22....b	35....b	48....d
10....C	23....a	36....d	49....c
11....M	24....b	37....a	50....b
12....G	25....c	38....b	
13....J	26....c	39....d	

Alternate Test 15

1....M	14....N	27....c	40....d
2....G	15....J	28....c	41....c
3....Q	16....d	29....b	42....c
4....B	17....d	30....b	43....d
5....O	18....a	31....d	44....b
6....D	19....b	32....c	45....c
7....E	20....c	33....b	46....C
8....H	21....d	34....a	47....F
9....F	22....c	35....b	48....A
10....P	23....d	36....c	49....D
11....L	24....a	37....c	50....B
12....I	25....c	38....b	
13....C	26....a	39....b	

Test 16 Chapters 33-34
Introduction to the Vertebrates, The Fishes

1....E	14....M	27....b	40....b
2....I	15....G	28....c	41....c
3....N	16....b	29....c	42....e
4....K	17....d	30....b	43....b
5....B	18....c	31....d	44....a
6....J	19....d	32....c	45....b
7....L	20....a	33....d	46....olfactory
8....P	21....d	34....b	lobe
9....C	22....b	35....a	47....cerebrum
10....Q	23....d	36....c	48....optic lobe
11....F	24....c	37....d	49....cerebellum
12....H	25....c	38....a	50....medulla
13....A	26....b	39....c	oblongata

Alternate Test 16

1....J	14....E	27....a	40....c
2....O	15....H	28....d	41....b
3....Q	16....c	29....c	42....d
4....L	17....c	30....c	43....c
5....A	18....b	31....d	44....b
6....D	19....b	32....c	45....a
7....M	20....a	33....c	46....ventral aorta
8....F	21....b	34....d	47....bulbus
9....I	22....b	35....b	arteriosus
10....G	23....d	36....a	48....atrium
11....P	24....c	37....d	(auricle)
12....K	25....d	38....d	49....sinus venosus
13....C	26....b	39....a	50....ventricle

Test 17 Chapters 35-36
The Amphibians and Reptiles

1....I	14....M	27....a	40....b
2....E	15....F	28....d	41....d
3....N	16....b	29....b	42....b
4....G	17....d	30....a	43....b
5....L	18....c	31....b	44....d
6....P	19....b	32....c	45....b
7....B	20....a	33....c	46....c
8....O	21....b	34....d	47....b
9....J	22....c	35....b	48....b
10....H	23....c	36....b	49....e
11....Q	24....b	37....a	50....d
12....C	25....d	38....c	
13....D	26....b	39....c	

Alternate Test 17

1....G	14....J	27....c	40....b
2....I	15....E	28....c	41....c
3....Q	16....b	29....c	42....d
4....L	17....d	30....d	43....d
5....B	18....c	31....b	44....b
6....N	19....c	32....c	45....d
7....A	20....a	33....b	46....olfactory lobe
8....H	21....b	34....c	47....cerebrum
9....F	22....d	35....d	48....optic lobe
10....D	23....d	36....a	49....cerebellum
11....P	24....b	37....d	50....medulla oblongata
12....M	25....a	38....d	
13....C	26....c	39....b	

Test 18 Chapters 37-38
The Birds and Mammals

1....D	15....J	29....b	43....C
2....H	16....c	30....c	44....H
3....O	17....d	31....b	45....G
4....G	18....d	32....c	46....egg
5....Q	19....b	33....b	(in ovary)
6....B	20....c	34....c	47....kidney
7....P	21....b	35....b	48....oviduct
8....I	22....d	36....E	49....lime-
9....F	23....b	37....I	producing
10....K	24....b	38....A	gland
11....N	25....a	39....F	(shell gland)
12....A	26....c	40....K	50....cloaca
13....E	27....c	41....D	
14....M	28....a	42....B	

Alternate Test 18

1....H	14....B	27....c	40....d
2....P	15....Q	28....d	41....c
3....K	16....c	29....d	42....e
4....O	17....d	30....a	43....c
5....C	18....b	31....b	44....a
6....L	19....b	32....d	45....d
7....F	20....c	33....b	46....olfactory
8....A	21....b	34....c	lobe
9....D	22....d	35....c	47....cerebrum
10....J	23....b	36....c	48....optic lobe
11....G	24....d	37....c	49....cerebellum
12....E	25....c	38....a	50....medulla
13....I	26....a	39....b	

Test 19 Chapters 39-40
The History of Man, The Body Framework

1....E	14....J	27....d	40....c
2....N	15....D	28....c	41....skeletal
3....P	16....c	29....c	42....muscular
4....A	17....b	30....a	43....digestive
5....O	18....c	31....b	44....respiratory
6....Q	19....d	32....d	45....circulatory
7....I	20....c	33....d	46....endocrine
8....C	21....c	34....b	47....excretory
9....K	22....d	35....c	48....integumentary
10....F	23....b	36....a	49....nervous
11....B	24....b	37....c	50....reproductive
12....L	25....b	38....b	
13....H	26....c	39....d	

Alternate Test 19

1....N	15....O	29....b	42....cranium (skull)
2....Q	16....c	30....b	43....clavicle (collarbone)
3....K	17....a	31....d	44....sternum (breastbone)
4....A	18....c	32....c	45....rib
5....D	19....c	33....c	46....vertebra
6....H	20....b	34....b	47....pelvis
7....M	21....d	35....d	48....femur
8....J	22....c	36....b	49....tibia
9....E	23....b	37....c	50....fibula
10....B	24....b	38....b	
11....I	25....d	39....a	
12....F	26....d	40....d	
13....G	27....a	41....humerus	
14....P	28....c		

Test 20 Chapter 41
Nutrition

1....F	14....J	27....c	40....A
2....O	15....E	28....a	41....C
3....I	16....c	29....b	42....B
4....Q	17....b	30....d	43....D
5....B	18....b	31....d	44....C
6....M	19....a	32....b	45....B
7....H	20....c	33....b	46....enamel
8....P	21....c	34....e	47....pulp cavity
9....D	22....d	35....d	48....gum
10....N	23....b	36....D	49....dentine
11....G	24....b	37....A	50....periodontal
12....L	25....c	38....B	membrane
13....A	26....d	39....C	

Alternate Test 20

1....I	14....P	27....c	40....C
2....H	15....L	28....c	41....B
3....J	16....c	29....d	42....A
4....A	17....d	30....a	43....D
5....N	18....c	31....b	44....B
6....Q	19....b	32....b	45....C
7....C	20....b	33....d	46....stomach
8....F	21....d	34....a	47....pylorus
9....B	22....b	35....d	48....colon (lge.
10....D	23....c	36....c	intestine)
11....G	24....b	37....C (D)	49....small
12....K	25....b	38....B	intestine
13....M	26....b	39....B	50....appendix

Test 21 Chapters 42-43
Transport, Excretion, Respiration, and Energy Exchange

1....G	16....c	31....d	44....aorta
2....C	17....c	32....a	45....pulmonary
3....O	18....b	33....c	artery
4....J	19....a	34....b	46....pulmonary
5....B	20....d	35....a	veins
6....F	21....b	36....d	47....left atrium
7....I	22....b	37....b	48....left A-V
8....K	23....d	38....c	valve (mitral
9....L	24....c	39....d	valve)
10....D	25....b	40....b	49....left ventricle
11....A	26....d	41....inferior vena	50....right
12....E	27....a	cava	ventricle
13....H	28....b	42....right atrium	
14....M	29....b	43....superior vena	
15....Q	30....b	cava	

Alternate Test 21

1....D	15....L	29....c	43....b
2....E	16....c	30....d	44....inferior vena
3....C	17....b	31....a	cava
4....I	18....d	32....c	45....right atrium
5....N	19....a	33....b	46....right
6....J	20....c	34....c	ventricle
7....M	21....c	35....d	47....pulmonary
8....A	22....d	36....a	veins
9....B	23....a	37....c	48....left atrium
10....P	24....b	38....d	49....left ventricle
11....F	25....b	39....b	50....aorta
12....G	26....c	40....a	
13....H	27....b	41....d	
14....Q	28....b	42....d	

Test 22 Chapters 44-45
Body Controls, Alcohol, Narcotics, and Tobacco

1....J	14....B	27....b	40....c
2....Q	15....K	28....b	41....e
3....M	16....c	29....d	42....c
4....I	17....c	30....d	43....d
5....H	18....a	31....c	44....b
6....N	19....b	32....a	45....c
7....P	20....b	33....b	46....meninges
8....A	21....d	34....c	47....cerebrum
9....G	22....a	35....d	48....cerebellum
10....F	23....c	36....b	49....medulla
11....L	24....c	37....c	50....spinal cord
12....E	25....a	38....a	
13....D	26....c	39....d	

Alternate Test 22

1....M	15....E	29....b	42....sensory neuron
2....G	16....d	30....b	
3....P	17....b	31....d	43....spinal cord
4....F	18....b	32....a	44....motor neuron
5....K	19....a	33....c	45....muscles of arm and hand
6....A	20....c	34....b	
7....I	21....b	35....b	46....iris
8....L	22....b	36....b	47....lens
9....D	23....d	37....c	48....cornea
10....Q	24....c	38....d	49....vitreous humor
11....B	25....c	39....c	
12....C	26....a	40....b	50....optic nerve
13....N	27....b	41....pain receptor in skin	
14....O	28....d		

Test 23

Chapters 46-47

Body Regulators, Reproduction and Development

1....F	14....A	27....b	40....c
2....I	15....G	28....c	41....F
3....C	16....b	29....c	42....F
4....N	17....b	30....c	43....H
5....H	18....c	31....b	44....A
6....Q	19....d	32....d	45....D
7....B	20....d	33....c	46....H
8....K	21....b	34....c	47....B
9....M	22....d	35....c	48....G
10....E	23....a	36....e	49....D
11....L	24....c	37....c	50....E
12....J	25....a	38....a	
13....P	26....c	39....d	

Alternate Test 23

1....F	14....G	27....a	40....b
2....N	15....D	28....b	41....F
3....C	16....c	29....c	42....A
4....J	17....b	30....b	43....B
5....M	18....b	31....c	44....C
6....I	19....c	32....c	45....F
7....B	20....d	33....d	46....F
8....H	21....a	34....b	47....H (A)
9....O	22....b	35....d	48....I
10....Q	23....d	36....b	49....F
11....A	24....c	37....d	50....G
12....E	25....b	38....a	
13....L	26....b	39....c	

Test 24 Chapters 48-49
Introduction to Ecology, The Habitat

1....Q	14....P	27....d	40....c
2....M	15....I	28....b	41....b
3....H	16....b	29....b	42....d
4....D	17....c	30....b	43....c
5....A	18....a	31....d	44....a
6....B	19....d	32....c	45....c
7....C	20....d	33....c	46....C
8....E	21....b	34....b	47....D
9....F	22....a	35....a	48....B
10....J	23....c	36....c	49....A
11....G	24....b	37....b	50....C
12....L	25....b	38....d	
13....O	26....b	39....c	

Alternate Test 24

1....I	14....F	27....d	40....d
2....N	15....E	28....c	41....c
3....A	16....c	29....a	42....c
4....K	17....b	30....c	43....a
5....O	18....b	31....d	44....b
6....Q	19....d	32....d	45....d
7....B	20....a	33....c	46....C
8....D	21....c	34....d	47....D
9....G	22....c	35....d	48....B
10....P	23....b	36....b	49....A
11....M	24....c	37....a	50....D
12....L	25....d	38....d	
13....H	26....b	39....a	

Test 25

Chapters 50-51

Periodic Changes in the Environment, Biogeography

1....M	14....L	27....d	40....b
2....Q	15....C	28....c	41....c
3....F	16....b	29....c	42....b
4....A	17....c	30....b	43....a
5....J	18....d	31....c	44....c
6....D	19....a	32....d	45....b
7....B	20....b	33....d	46....e
8....P	21....b	34....a	47....d
9....N	22....c	35....b	48....d
10....K	23....b	36....c	49....c
11....O	24....d	37....b	50....b
12....I	25....c	38....c	
13....E	26....d	39....d	

Alternate Test 25

1....G	14....D	27....a	40....b
2....M	15....E	28....d	41....b
3....N	16....d	29....d	42....c
4....L	17....c	30....a	43....d
5....Q	18....c	31....c	44....a
6....C	19....a	32....b	45....c
7....F	20....c	33....d	46....d
8....O	21....b	34....c	47....b
9....H	22....c	35....c	48....e
10....A	23....b	36....a	49....d
11....B	24....b	37....c	50....b
12....I	25....d	38....b	
13....K	26....a	39....d	

Test 26 Chapters 52-53
Conservation of Natural Resources

1....C	19....b	34....sheet erosion	water and soil
2....N	20....d	35....block cutting	conservation
3....Q	21....a	36....game fish	47....dredging and
4....M	22....d	37....conservation	straightening
5....H	23....b	38....wind erosion	of river
6....G	24....c	39....fish ladder	channels
7....D	25....b	40....oxygen	48....dams across
8....D	26....a	41....passenger	rivers
9....E	27....d	pigeon	49....floods
10....B	28....b	42....the water	50....pollution by
11....L	29....d	table (ground	garbage,
12....O	30....b	water)	sewage,
13....P	31....southern	43....rill erosion	industrial
14....K	forest	44....crop rotation	waste (water
15....I	32....beaver	45....topsoil	with too much
16....d	33....potash	46....lowered	mud and silt,
17....d	(potassium	water levels	indiscrimi-
18....c	compound)	due to poor	nate stocking)

Alternate Test 26

1....B	14....N	27....d	40....c
2....I	15....G	28....a	41....b
3....H	16....b	29....c	42....c
4....L	17....d	30....b	43....a
5....Q	18....c	31....b	44....b
6....E	19....c	32....c	45....a
7....A	20....a	33....d	46....e
8....O	21....d	34....b	47....d
9....F	22....b	35....c	48....b
10....C	23....b	36....d	49....d
11....K	24....c	37....d	50....c
12....D	25....d	38....a	
13....P	26....a	39....b	

Second Semester Final Chapters 27-53
Part 1: Biology of the Invertebrates

- | | |
|---------|---------|
| 1....c | 14....b |
| 2....b | 15....b |
| 3....d | 16....d |
| 4....d | 17....c |
| 5....c | 18....a |
| 6....b | 19....b |
| 7....c | 20....d |
| 8....d | 21....d |
| 9....c | 22....a |
| 10....a | 23....b |
| 11....b | 24....c |
| 12....d | 25....c |
| 13....a | |

Part 2: Biology of the Vertebrates

- | | |
|---|--|
| 26....notochord | 38....gill arches (gills) |
| 27....laying eggs | 39....duckbilled platypus (spiny anteater) |
| 28....placenta | 40....instincts |
| 29....cerebrum | 41....sinus venosus |
| 30....reproduce | 42....mammary gland |
| 31....amniote egge (egg contained in a shell) | 43....yolk |
| 32....circulatory system (blood) | 44....crop |
| 33....vertebrae | 45....skeleton |
| 34....viviporous | 46....cerebrum |
| 35....mammals | 47....quill feather |
| 36....amphibians | 48....arteries |
| 37....3-chambered heart | 49....conditioned reaction |
| | 50....Marsupialia |

Part 3: The Biology of Man

- | | |
|---------|---------|
| 51....b | 64....c |
| 52....d | 65....b |
| 53....d | 66....c |
| 54....c | 67....c |
| 55....d | 68....a |
| 56....b | 69....b |
| 57....b | 70....a |
| 58....c | 71....b |
| 59....b | 72....b |
| 60....c | 73....d |
| 61....a | 74....b |
| 62....d | 75....c |
| 63....b | |

Part 4: Ecological Relationships

- | | |
|---------|---------------------------|
| 76....I | 89....J |
| 77....B | 90....P |
| 78....Q | 91....producers |
| 79....K | 92....erosion |
| 80....O | 93....succession |
| 81....L | 94....desert |
| 82....G | 95....contour farming |
| 83....C | 96....nitrates (nitrogen) |
| 84....H | 97....mimicry |
| 85....A | 98....oxygen |
| 86....E | 99....migration |
| 87....M | 100....pioneers |
| 88....F | |

Alternate Second Semester Final Chapters 27-53

Part 1: Biology of the Invertebrates

- | | |
|---------|--------------------------|
| 1....K | 14....L |
| 2....M | 15....Q |
| 3....J | 16....bilateral |
| 4....N | 17....Echinodermata |
| 5....E | 18....butterfly |
| 6....I | 19....degeneration |
| 7....G | 20....excretion |
| 8....F | 21....the planarian |
| 9....B | 22....sponges |
| 10....D | 23....drones (male bees) |
| 11....A | 24....scorpion |
| 12....C | 25....pork |
| 13....P | |

Part 2: Biology of the Vertebrates

- | | |
|---------|---------|
| 26....b | 39....a |
| 27....c | 40....b |
| 28....a | 41....d |
| 29....d | 42....c |
| 30....d | 43....a |
| 31....a | 44....c |
| 32....d | 45....b |
| 33....b | 46....d |
| 34....c | 47....b |
| 35....d | 48....c |
| 36....b | 49....d |
| 37....b | 50....b |
| 38....c | |

Part 3: The Biology of Man

- | | |
|----------------------------------|---|
| 51....hormone | 64....amnion |
| 52....brain | 65....enamel |
| 53....gall bladder | 66....red corpuscles (hemoglobin molecules) |
| 54....stomach | 67....cones |
| 55....smooth muscle | 68....arteries |
| 56....thyroid | 69....bone |
| 57....oxygen | 70....pancreas |
| 58....left atrium (left auricle) | 71....glucose |
| 59....small intestine | 72....diaphragm |
| 60....pituitary | 73....nerve endings |
| 61....tendon | 74....clotting |
| 62....middle ear | 75....narcotic |
| 63....ball and socket | |

Part 4: Ecological Relationships

- | | |
|---------|----------|
| 76....c | 89....b |
| 77....d | 90....a |
| 78....b | 91....b |
| 79....b | 92....b |
| 80....b | 93....d |
| 81....c | 94....a |
| 82....d | 95....a |
| 83....c | 96....d |
| 84....a | 97....b |
| 85....d | 98....b |
| 86....d | 99....d |
| 87....c | 100....c |
| 88....b | |

DATE DUE SLIP

	RETURN JUN 30 '81
OCT 10 RETURN	DUE EDUC NOV 16 '81
EDUC NOV 12 '79	
NOV - 8 RETURN	RETURN NOV 21 '81
SE EDUC DEC 25 '79	DUE EDUC. MAR 16 '82
DEC 20 RETURN	MAR 23 '82
MAR 1 '80	RETURN MAR 18 '82
MAR 10 RETURN	
	RETURN APR 23 '82
EDUC MAR 21 '80	DUE EDUC NOV 15 '82
EDUC MAR 28 '80	RETURN NOV 15 '82
DUE EDUC APR 7 '80	DUE EDUC FEB 25 '83
APR 10 RETURN	RETURN FEB 23 '83
	DUE EDUC OCT 15 '83
	RETURN OCT 16 '83
FEB 11 RETURN	DUE EDUC NOV 17 '83
DUE EDUC MAR 18 '81	RETURN NOV 18 '83
RETURN MAR 27 '81	
	DUE EDUC AUG 31 '84
	AUG 29 RETURN

QH 307 M818 1965 TCH-GD-
OTTO JAMES H JAMES HOWARD
MODERN BIOLOGY

NL 39128058 CURR HIST



000000686386

QH 307 M818 1965 Tch.gd.
Otto, James Howard.
Modern biology.

0028370B CURR

